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A TEXTBOOK

ON

PLUMBING, HEATING, AND VENTILATION

INTERNATIONAL CORRESPONDENCE SCHOOLS
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5

ANSWERS TO QUESTIONS
TABLES AND FORMULAS

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A KEY

TO ALL THE

QUESTIONS AND EXAMPLES

CONTAINED IN THE

EXAMINATION QUESTIONS

INCLUDED IN THE PRECEDING VOLUMES.

The Keys that follow have been divided into sections corresponding to the Examination Questions to which they refer. The answers and solutions have been numbered to correspond with the questions. When the answer to a question involves a repetition of statements given in the Instruction Paper, the reader has been referred to a numbered article, the reading of which will enable him to answer the question himself.

To be of the greatest benefit, the Keys should be used sparingly. They should be used much in the same manner as a pupil would go to a teacher for instruction with regard to answering some example he was unable to solve. If used in this manner, the Keys will be of great help and assistance to the student, and will be a source of encouragement to him in studying the various papers composing the Course.

CONTENTS.

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ARITHMETIC.

(QUESTIONS 1-91.)

(1) See Art. **1.**

(2) See Art. **3.**

(3) See Arts. **5** and **6.**

(4) See Arts. **10** and **11.**

(5) 980 = Nine hundred eighty.

605 = Six hundred five.

28,284 = Twenty-eight thousand, two hundred eighty-four.

9,006,042 = Nine million, six thousand and forty-two.

850,317,002 = Eight hundred fifty million, three hundred seventeen thousand and two.

700,004 = Seven hundred thousand and four.

(6) Seven thousand six hundred = 7,600.

Eighty-one thousand four hundred two = 81,402.

Five million, four thousand and seven = 5,004,007.

One hundred and eight million, ten thousand and one = 108,010,001.

Eighteen million and six = 18,000,006.

Thirty thousand and ten = 30,010.

(7) In adding whole numbers, place the numbers to be added directly under each other so that the extreme right-hand figures will stand in the same column, regardless of the position of those at the left. Add the first column of figures at the extreme right, which equals 19 units, or 1 ten and 9 units. We place 9 units under the units column, and reserve 1 ten for the column

$$\begin{array}{r} 3290 \\ 504 \\ 865403 \\ 2074 \\ 81 \\ 7 \\ \hline 871359 \end{array} \text{ Ans.}$$

of tens. $1 + 8 + 7 + 9 = 25$ tens, or 2 hundreds and 5 tens. Place 5 tens under the tens column, and reserve 2 hundreds for the hundreds column. $2 + 4 + 5 + 2 = 13$ hundreds, or 1 thousand and 3 hundreds. Place 3 hundreds under the hundreds column, and reserve the 1 thousand for the thousands column. $1 + 2 + 5 + 3 = 11$ thousands, or 1 ten-thousand and 1 thousand. Place the 1 thousand in the column of thousands, and reserve the 1 ten-thousand for the column of ten-thousands. $1 + 6 = 7$ ten-thousands. Place this seven ten-thousands in the ten-thousands column. There is but one figure 8 in the hundreds of thousands place in the numbers to be added, so it is placed in the hundreds of thousands column of the sum.

A simpler (though less scientific) explanation of the same problem is the following: $7 + 1 + 4 + 3 + 4 + 0 = 19$; write the nine and reserve the 1. $1 + 8 + 7 + 0 + 0 + 9 = 25$; write the 5 and reserve the 2. $2 + 0 + 4 + 5 + 2 = 13$; write the 3 and reserve the 1. $1 + 2 + 5 + 3 = 11$; write the 1 and reserve 1. $1 + 6 = 7$; write the 7. Bring down the 8 to its place in the sum.

(8)

$$\begin{array}{r} 709 \\ 8304725 \\ 391 \\ 100302 \\ 300 \\ 909 \\ \hline 8407336 \end{array} \text{ Ans.}$$

(9) (*a*) In subtracting whole numbers, place the subtrahend or smaller number under the minuend or larger number, so that the right-hand figures stand directly under each other. Begin *at the right* to subtract. We can not subtract 8 units from 2 units, so we take 1 ten from the 6 tens and add it to the 2 units. As 1 *ten* = 10 *units*, we have 10 units + 2 units = 12 units. Then, 8 units from 12 units leaves 4 units. We took 1 ten from 6 tens, so

only 5 tens remain. 3 tens from 5 tens leaves 2 tens. In the hundreds column we have 3 hundreds from 9 hundreds leaves 6 hundreds. We can not subtract 3 thousands from 0 thousands, so we take 1 ten-thousand from 5 ten-thousands and add it to the 0 thousands. 1 *ten-thousand* = 10 *thousands*, and 10 thousands + 0 thousands = 10 thousands. Subtracting, we have 3 thousands from 10 thousands leaves 7 thousands. We took 1 ten-thousand from 5 ten-thousands and have 4 ten-thousands remaining. Since there are no ten-thousands in the subtrahend, the 4 in the ten-thousands column in the minuend is brought down into the same column in the remainder, because 0 from 4 leaves 4.

$$\begin{array}{r} 50962 \\ 3338 \\ \hline 47624 \end{array} \text{ Ans.}$$

(*b*)
$$\begin{array}{r} 15339 \\ 10001 \\ \hline 5338 \end{array} \text{ Ans.}$$

(10) (*a*)
$$\begin{array}{r} 70968 \\ 32975 \\ \hline 37993 \end{array} \text{ Ans.}$$

(*b*)
$$\begin{array}{r} 100000 \\ 98735 \\ \hline 1265 \end{array} \text{ Ans.}$$

(11) We have given the minuend or greater number (1,004) and the difference or remainder (49). Placing these in the usual form of subtraction we have $\begin{array}{r} 1004 \\ \text{——} \\ \hline 49 \end{array}$ in which the dash (——) represents the number sought. This number is evidently *less* than 1,004 by the difference 49, hence, 1,004 − 49 = 955, the smaller number. For the sum of the two numbers we then have

$$\begin{array}{rl} 1004 & \textit{larger} \\ 955 & \textit{smaller} \\ \hline 1959 & \textit{sum.} \end{array} \text{ Ans.}$$

Or, this problem may be solved as follows: If the greater of two numbers is 1,004, and the difference between them is 49, then it is evident that the smaller number must be equal to the difference between the greater number (1,004)

and the difference (49); or, 1,004 − 49 = 955, the smaller number. Since the greater number equals 1,004 and the smaller number equals 955, their sum equals 1,004 + 955 = 1,959 sum. Ans.

(12) The numbers connected by the plus (+) sign must first be added. Performing these operations we have

```
   5962          3874
   8471          2039
   9023          ----
  -----          5913 sum.
  23456 sum.
```

Subtracting the smaller number (5,913) from the greater (23,456) we have

```
23456
 5913
-----
17543 difference. Ans.
```

(13) $44675 = amount willed to his son.
26380 = amount willed to his daughter.
$71055 = amount willed to his two children.
$125000 = amount willed to his wife and two children.
71055 = amount willed to his two children.
$53945 = amount willed to his wife. Ans.

(14) In the multiplication of whole numbers, place the multiplier under the multiplicand, and multiply each term of the multiplicand by each term of the multiplier, writing the right-hand figure of each product obtained under the term of the multiplier which produces it.

(*a*)

```
 526387
      7
-------
3684709 Ans.
```

7 × 7 units = 49 units, or 4 tens and 9 units. We write the 9 units and reserve the 4 tens. 7 times 8 tens = 56 tens; 56 tens + 4 tens reserved = 60 tens or 6 hundreds and 0 tens. Write the 0 tens and reserve the 6 hundreds. 7 × 3 hundreds = 21 hundreds; 21 + 6 hundreds reserved = 27 hundreds, or 2 thousands and 7 hundreds. Write the 7 hundreds and reserve

the 2 thousands. 7×6 thousands $= 42$ thousands; $42 + 2$ thousands reserved $= 44$ thousands or 4 ten-thousands and 4 thousands. Write the 4 thousands and reserve the 4 ten-thousands. 7×2 ten-thousands $= 14$ ten-thousands; $14 + 4$ ten-thousands reserved $= 18$ ten-thousands, or 1 hundred-thousand and 8 ten-thousands. Write the 8 ten-thousands and reserve the 1 hundred-thousand. 7×5 hundred-thousands $= 35$ hundred-thousands; $35 + 1$ hundred-thousand reserved $= 36$ hundred-thousands. Since there are no more figures in the multiplicand to be multiplied, we write the 36 hundred-thousands in the product. This completes the multiplication.

A simpler (though less scientific) explanation of the same problem is the following:

7 times $7 = 49$; write the 9 and reserve the 4. 7 times $8 = 56$; $56 + 4$ reserved $= 60$; write the 0 and reserve the 6. 7 times $3 = 21$; $21 + 6$ reserved $= 27$; write the 7 and reserve the 2. $7 \times 6 = 42$; $42 + 2$ reserved $= 44$; write the 4 and reserve 4. $7 \times 2 = 14$; $14 + 4$ reserved $= 18$; write the 8 and reserve the 1. $7 \times 5 = 35$; $35 + 1$ reserved $= 36$; write the 36.

In this case the multiplier is 17 *units*, or 1 *ten* and 7 *units*, so that the product is obtained by adding two partial products, namely, $7 \times 700{,}298$ and $10 \times 700{,}298$. The actual operation is performed as follows:

$$
(b)\quad
\begin{array}{r}
700298 \\
17 \\
\hline
4902086 \\
700298 \\
\hline
11905066
\end{array}
\quad \text{Ans.}
$$

7 times $8 = 56$; write the 6 and reserve the 5. 7 times $9 = 63$; $63 + 5$ reserved $= 68$; write the 8 and reserve the 6. 7 times $2 = 14$; $14 + 6$ reserved $= 20$; write the 0 and reserve the 2. 7 times $0 = 0$; $0 + 2$ reserved $= 2$; write the 2. 7 times $0 = 0$; $0 + 0$ reserved $= 0$; write the 0. 7 times $7 = 49$; $49 + 0$ reserved $= 49$; write the 49.

To multiply by the 1 ten we say 1 times $700298 = 700298$, and write 700298 under the first partial product, as shown, with the right-hand figure 8 under the multiplier 1. Add the two partial products; their sum equals the entire product.

(*c*) Multiply any two of the numbers together and multiply their product by the third number.

```
      217
      103
      ---
      651
     2170
    -----
    22351
       67
   ------
   156457
  134106
  -------
  1497517  Ans.
```

(15) If your watch ticks every second, then to find how many times it ticks in one week it is necessary to find the number of seconds in 1 week.

```
     60 seconds = 1 minute.
     60 minutes = 1 hour.
   ----
   3600 seconds = 1 hour.
     24 hours = 1 day.
  -----
  14400
  7200
  -----
  86400 seconds = 1 day.
      7 days = 1 week.
 ------
 604800 seconds in 1 week or the number of times that
  Ans.     your watch ticks in 1 week.
```

(16) If a monthly publication contains 24 pages, a yearly volume will contain 12×24 or 288 pages, since there are 12 months in one year; and eight yearly volumes will contain 8×288, or 2,304 pages.

```
   24
   12
  ---
  288
    8
 ----
 2304  Ans.
```

(17) If an engine and boiler are worth $3,246, and the building is worth 3 times as much, plus $1,200, then the building is worth

```
        $3246
            3
         ----
         9738
 plus    1200
       ------
       $10938 = value of building.
```

If the tools are worth twice as much as the building, plus \$1,875, then the tools are worth

$$
\begin{array}{rr}
 & \$10938 \\
 & 2 \\
\hline
 & 21876 \\
\text{plus} & 1875 \\
\hline
 & \$23751
\end{array} = \text{value of tools.}
$$

$$
\begin{array}{lr}
\text{Value of building} = & \$10938 \\
\text{Value of tools} \quad = & 23751 \\
\hline
 & \$34689
\end{array} = \text{value of the building and tools. } (a) \text{ Ans.}
$$

$$
\begin{array}{lr}
\text{Value of engine and boiler} = & \$\ 3246 \\
\text{Value of building and tools} = & 34689 \\
\hline
 & \$37935
\end{array} = \text{value of the whole plant. } (b) \text{ Ans.}
$$

(18) (*a*) $(72 \times 48 \times 28 \times 5) \div (96 \times 15 \times 7 \times 6)$.

Placing the numerator over the denominator the problem becomes

$$\frac{72 \times 48 \times 28 \times 5}{96 \times 15 \times 7 \times 6} = ?$$

The 5 in the *dividend* and 15 in the *divisor* are both *divisible* by 5, since 5 divided by 5 equals 1, and 15 divided by 5 equals 3. *Cross off* the 5 and write the 1 *over* it; also *cross off* the 15 and write the 3 *under* it. Thus,

$$\frac{72 \times 48 \times 28 \times \overset{1}{\cancel{5}}}{96 \times \underset{3}{\cancel{15}} \times 7 \times 6} =$$

The 5 and 15 are *not* to be considered any longer, and, in fact, may be erased entirely and the 1 and 3 placed in their stead, and treated as if the 5 and 15 *never* existed. Thus,

$$\frac{72 \times 48 \times 28 \times 1}{96 \times 3 \times 7 \times 6} =$$

72 in the *dividend* and 96 in the *divisor* are *divisible* by 12, since 72 divided by 12 equals 6, and 96 divided by 12 equals 8. *Cross off* the 72 and write the 6 *over* it; also, *cross off* the 96 and write the 8 *under* it. Thus,

$$\frac{\overset{6}{\cancel{72}} \times 48 \times 28 \times 1}{\underset{8}{\cancel{96}} \times 3 \times 7 \times 6} =$$

The 72 and 96 are *not* to be considered any longer, and, in fact, may be *erased* entirely and the 6 and 8 placed in their stead, and treated as if the 72 and 96 *never* existed. Thus,

$$\frac{6 \times 48 \times 28 \times 1}{8 \times 3 \times 7 \times 6} =$$

Again, 28 in the *dividend* and 7 in the *divisor* are *divisible* by 7, since 28 divided by 7 equals 4, and 7 divided by 7 equals 1. *Cross off* the 28 and write the 4 *over* it; also, cross off the 7 and write the 1 *under* it. Thus,

$$\frac{6 \times 48 \times \overset{4}{\cancel{28}} \times 1}{8 \times 3 \times \underset{1}{\cancel{7}} \times 6} =$$

The 28 and 7 are *not* to be considered any longer, and, in fact, may be *erased* entirely and the 4 and 1 placed in their stead, and treated as if the 28 and 7 *never* existed. Thus,

$$\frac{6 \times 48 \times 4 \times 1}{8 \times 3 \times 1 \times 6} =$$

Again, 48 in the *dividend* and 6 in the *divisor* are *divisible* by 6, since 48 divided by 6 equals 8, and 6 divided by 6 equals 1. *Cross off* the 48 and write the 8 *over* it; also, cross off the 6 and write the 1 *under* it. Thus,

$$\frac{6 \times \overset{8}{\cancel{48}} \times 4 \times 1}{8 \times 3 \times 1 \times \underset{1}{\cancel{6}}} =$$

The 48 and 6 are *not* to be considered any longer, and, in fact, may be *erased* entirely and the 8 and 1 placed in their stead, and treated as if the 48 and 6 *never* existed. Thus,

$$\frac{6 \times 8 \times 4 \times 1}{8 \times 3 \times 1 \times 1} =$$

Again, 6 in the *dividend* and 3 in the *divisor* are *divisible* by 3, since 6 divided by 3 equals 2, and 3 divided by 3 equals 1. *Cross off* the 6 and write the 2 *over* it; also, cross off the 3 and write the 1 *under* it. Thus,

$$\frac{\overset{2}{\cancel{6}} \times 8 \times 4 \times 1}{8 \times \underset{1}{\cancel{3}} \times 1 \times 1} =$$

The 6 and 3 are *not* to be considered any longer, and, in fact, may be *erased* entirely and the 2 and 1 placed in their stead, and treated as if the 6 and 3 *never* existed. Thus,

$$\frac{2 \times 8 \times 4 \times 1}{8 \times 1 \times 1 \times 1} =$$

Canceling the 8 in the dividend and the 8 in the divisor, the result is

$$\frac{2 \times \overset{1}{\cancel{8}} \times 4 \times 1}{\underset{1}{\cancel{8}} \times 1 \times 1 \times 1} = \frac{2 \times 1 \times 4 \times 1}{1 \times 1 \times 1 \times 1}.$$

Since there are *no two remaining numbers* (one in the dividend and one in the divisor) *divisible* by *any number* except 1, without a remainder, it is *impossible* to cancel further.

Multiply all the *uncanceled numbers* in the *dividend* together, and divide their *product* by the *product* of all the *uncanceled* numbers in the divisor. The *result* will be the *quotient*. The *product* of all the *uncanceled numbers* in the *dividend* equals $2 \times 1 \times 4 \times 1 = 8$; the product of all the *uncanceled* numbers in the *divisor* equals $1 \times 1 \times 1 \times 1 = 1$.

Hence, $$\frac{2 \times 1 \times 4 \times 1}{1 \times 1 \times 1 \times 1} = \frac{8}{1} = 8. \quad \text{Ans.}$$

Or, $$\frac{\overset{\overset{2}{\cancel{6}}}{\cancel{72}} \times \overset{\cancel{8}}{\cancel{48}} \times \overset{4}{\cancel{28}} \times \overset{1}{\cancel{5}}}{\underset{\underset{1}{\cancel{8}}}{\cancel{96}} \times \underset{\underset{1}{\cancel{3}}}{\cancel{15}} \times \cancel{7} \times \underset{1}{\cancel{6}}} = \frac{8}{1} = 8. \quad \text{Ans}$$

(*b*) $(80 \times 60 \times 50 \times 16 \times 14) \div (70 \times 50 \times 24 \times 20)$.

Placing the numerator over the denominator, the problem becomes

$$\frac{80 \times 60 \times 50 \times 16 \times 14}{70 \times 50 \times 24 \times 20} = ?$$

The 50 in the *dividend* and 70 in the *divisor* are both *divisible* by 10, since 50 divided by 10 equals 5, and 70 divided by 10 equals 7. *Cross off* the 50 and write the 5 *over* it; also, *cross off* the 70 and write the 7 *under* it. Thus,

$$\frac{80 \times 60 \times \overset{5}{\cancel{50}} \times 16 \times 14}{\underset{7}{\cancel{70}} \times 50 \times 24 \times 20} =$$

The 50 and 70 are not to be considered any longer, and, in fact, may be erased entirely and the 5 and 7 placed in their stead, and treated as if the 50 and 70 *never* existed. Thus,

$$\frac{80 \times 60 \times 5 \times 16 \times 14}{7 \times 50 \times 24 \times 20} =$$

Also, 80 in the *dividend* and 20 in the *divisor* are *divisible* by 20, since 80 divided by 20 equals 4, and 20 divided by 20 equals 1. Cross off the 80 and write the 4 *over* it; also, cross off the 20 and write the 1 *under* it. Thus,

$$\frac{\overset{4}{\cancel{80}} \times 60 \times 5 \times 16 \times 14}{7 \times 50 \times 24 \times \underset{1}{\cancel{20}}} =$$

The 80 and 20 are *not* to be considered any longer, and, in fact, may be erased entirely and the 4 and 1 placed in their stead, and treated as if the 80 and 20 *never* existed. Thus,

$$\frac{4 \times 60 \times 5 \times 16 \times 14}{7 \times 50 \times 24 \times 1} =$$

Again, 16 in the *dividend* and 24 in the *divisor* are *divisible* by 8, since 16 divided by 8 equals 2, and 24 divided by 8 equals 3. *Cross off* the 16 and write the 2 *over* it; also cross off the 24 and write the 3 *under* it. Thus,

$$\frac{4 \times 60 \times 5 \times \overset{2}{\cancel{16}} \times 14}{7 \times 50 \times \underset{3}{\cancel{24}} \times 1} =$$

The 16 and 24 are not to be considered any longer, and, in fact, may be erased entirely and the 2 and 3 placed in their stead, and treated as if the 16 and 24 *never* existed. Thus,

$$\frac{4 \times 60 \times 5 \times 2 \times 14}{7 \times 50 \times 3 \times 1} =$$

Again, 60 in the *dividend* and 50 in the *divisor* are *divisible* by 10, since 60 divided by 10 equals 6, and 50 divided by 10 equals 5. *Cross off* the 60 and write the 6 *over* it; also, cross off the 50 and write the 5 *under* it. Thus,

$$\frac{4 \times \overset{6}{\cancel{60}} \times 5 \times 2 \times 14}{7 \times \underset{5}{\cancel{50}} \times 3 \times 1} =$$

The 60 and 50 are not to be considered any longer, and, in fact, may be erased entirely and the 6 and 5 placed in their stead, and treated as if the 60 and 50 *never* existed. Thus,

$$\frac{4 \times 6 \times 5 \times 2 \times 14}{7 \times 5 \times 3 \times 1} =$$

The 14 in the *dividend* and 7 in the *divisor* are *divisible* by 7, since 14 divided by 7 equals 2, and 7 divided by 7 equals 1. *Cross off* the 14 and write the 2 *over* it; also, cross off the 7 and write the 1 *under* it. Thus,

$$\frac{4 \times 6 \times 5 \times 2 \times \overset{2}{\cancel{14}}}{\underset{1}{\cancel{7}} \times 5 \times 3 \times 1} =$$

The 14 and 7 are not to be considered any longer, and, in fact, may be erased entirely and the 2 and 1 placed in their stead, and treated as if the 14 and 7 *never* existed. Thus,

$$\frac{4 \times 6 \times 5 \times 2 \times 2}{1 \times 5 \times 3 \times 1} =$$

The 5 in the *dividend* and 5 in the *divisor* are *divisible* by 5, since 5 divided by 5 equals 1. *Cross off* the 5 of the *dividend* and write the 1 *over* it; also, cross off the 5 of the *divisor* and write the 1 *under* it. Thus,

$$\frac{4 \times 6 \times \overset{1}{\cancel{5}} \times 2 \times 2}{1 \times \underset{1}{\cancel{5}} \times 3 \times 1} =$$

The 5 in the *dividend* and 5 in the *divisor* are not to be considered any longer, and, in fact, may be erased entirely and 1 and 1 placed in their stead, and treated as if the 5 and 5 *never* existed. Thus,

$$\frac{4 \times 6 \times 1 \times 2 \times 2}{1 \times 1 \times 3 \times 1} =$$

The 6 in the *dividend* and 3 in the *divisor* are *divisible* by 3, since 6 divided by 3 equals 2, and 3 divided by 3 equals 1. *Cross off* the 6 and place 2 *over* it; also, cross off the 3 and place 1 *under* it. Thus,

$$\frac{4 \times \overset{2}{\cancel{6}} \times 1 \times 2 \times 2}{1 \times 1 \times \underset{1}{\cancel{3}} \times 1} =$$

The 6 and 3 are not to be considered any longer, and, in fact, may be erased entirely and 2 and 1 placed in their stead, and treated as if the 6 and 3 *never* existed. Thus,

$$\frac{4 \times 2 \times 1 \times 2 \times 2}{1 \times 1 \times 1 \times 1} = \frac{32}{1} = 32. \quad \text{Ans.}$$

$$\text{Hence, } \frac{\overset{4}{\cancel{80}} \times \overset{\overset{2}{\cancel{6}}}{\cancel{60}} \times \overset{\overset{1}{\cancel{5}}}{\cancel{50}} \times \overset{2}{\cancel{16}} \times \overset{2}{\cancel{14}}}{\underset{\underset{1}{\cancel{7}}}{\cancel{70}} \times \underset{\underset{1}{\cancel{5}}}{\cancel{50}} \times \underset{\underset{1}{\cancel{3}}}{\cancel{24}} \times \underset{1}{\cancel{20}}} = \frac{4 \times 2 \times 1 \times 2 \times 2}{1 \times 1 \times 1 \times 1} = \frac{32}{1} = 32. \quad \text{Ans.}$$

(19) 28 acres of land at $133 an acre would cost $28 \times \$133 = \$3,724$.

```
  28
----
1064
 266
----
$3724
```

If a mechanic earns \$1,500 a year and his expenses are \$968 per year, then he would save \$1500—\$968, or \$532 per year.

$$\begin{array}{r} \$1500 \\ 968 \\ \hline \$532 \end{array}$$

If he saves \$532 in 1 year, to save \$3,724 it would take as many years as \$532 is contained times in \$3,724, or 7 years.

$$\begin{array}{l} 532\,)\,3724\,(\,7 \text{ years. Ans.} \\ \underline{3724} \end{array}$$

(20) If the freight train ran 365 miles in one week, and 3 times as far lacking 246 miles the next week, then it ran (3×365 miles) $-$ 246 miles, or 849 miles the second week. Thus,

$$\begin{array}{lr} & 365 \\ & 3 \\ \hline & 1095 \\ & 246 \\ \hline \textit{difference} & 849 \text{ miles. Ans.} \end{array}$$

(21) The distance from Philadelphia to Pittsburg is 354 miles. Since there are 5,280 feet in one mile, in 354 miles there are $354 \times 5,280$ feet, or 1,869,120 feet. If the driving wheel of the locomotive is 16 feet in circumference, then in going from Philadelphia to Pittsburg, a distance of 1,869,-120 feet, it will make $1,869,120 \div 16$, or 116,820 revolutions.

$$\begin{array}{l} 16)1869120(116820 \text{ rev. Ans.} \\ \underline{16} \\ 26 \\ \underline{16} \\ 109 \\ \underline{96} \\ 131 \\ \underline{128} \\ 32 \\ \underline{32} \\ 0 \end{array}$$

(22) (*a*)

```
576)589824(1024  Ans.
    576
    ----
     1382
     1152
     ----
      2304
      2304
      ----
```

(*b*)

```
43911)369730620(8420  Ans.
      351288
      ------
       184426
       175644
       ------
         87822
         87822
         -----
             0
```

(*c*)

```
505)2527525(5005  Ans.
    2525
    -------
       2525
       2525
       ----
```

(*d*)

```
1234)4961794302(4020903  Ans.
     4936
     ----
       2579
       2468
       -----
        11143
        11106
        -----
          3702
          3702
          ----
```

(23) The harness evidently cost the difference between \$444 and the amount which he paid for the horse and wagon.

Since \$264 + \$153 = \$417, the amount paid for the horse and wagon, \$444 − \$417 = \$27, the cost of the harness.

```
$264          $444
 153           417
----          ----
$417           $27  Ans.
```

(**24**) (*a*)

```
   1024
    576
   ----
   6144
  7168
 5120
 ------
 589824  Ans
```

(*b*)

```
    5005
     505
   -----
   25025
 250250
 -------
 2527525  Ans.
```

(*c*)

```
    43911
     8420
   ------
   878220
 175644
351288
---------
369730620  Ans.
```

(**25**) Since there are 12 months in a year, the number of days the man works is $25 \times 12 = 300$ days. As he works 10 hours each day, the number of hours that he works in one year is $300 \times 10 = 3,000$ hours. Hence, he receives for his work $3,000 \times 30 = 90,000$ cents, or $90,000 \div 100 = \$900$. Ans.

(**26**) See Art. **71.**

(**27**) See Art. **77.**

(**28**) See Art. **73.**

(**29**) See Art. **73.**

(**30**) See Art. **75.**

(**31**) $\frac{13}{8}$ is an improper fraction, since its numerator 13 is greater than its denominator 8.

(**32**) $4\frac{1}{2}$; $14\frac{3}{10}$; $85\frac{4}{19}$.

(33) To reduce a fraction to its lowest terms means to change its form without changing its value. In order to do this, we must divide both numerator and denominator by the same number until we can no longer find any number (except 1) which will divide both of these terms without a remainder.

To reduce the fraction $\frac{4}{8}$ to its lowest terms we divide both numerator and denominator by 4, and obtain as a result the fraction $\frac{1}{2}$. Thus, $\frac{4 \div 4}{8 \div 4} = \frac{1}{2}$; similarly, $\frac{4 \div 4}{16 \div 4} = \frac{1}{4}$; $\frac{8 \div 4}{32 \div 4} = \frac{2 \div 2}{8 \div 2} = \frac{1}{4}$; $\frac{32 \div 8}{64 \div 8} = \frac{4 \div 4}{8 \div 4} = \frac{1}{2}$. Ans.

(34) When the denominator of any number is not expressed, it is understood to be 1, so that $\frac{6}{1}$ is the same as $6 \div 1$, or 6. To reduce $\frac{6}{1}$ to an improper fraction whose denominator is 4, we must multiply both numerator and denominator by some number which will make the denominator of 6 equal to 4. Since this denominator is 1, by multiplying both terms of $\frac{6}{1}$ by 4 we shall have $\frac{6 \times 4}{1 \times 4} = \frac{24}{4}$, which has the *same value* as 6, but has a *different form*. Ans.

(35) In order to reduce a mixed number to an improper fraction, we must *multiply the whole number by the denominator of the fraction* and *add the numerator of the fraction to that product*. This *result* is the *numerator of the improper fraction*, of which the *denominator is the denominator of the fractional part of the mixed number*.

$7\frac{7}{8}$ means the same as $7 + \frac{7}{8}$. In 1 there are $\frac{8}{8}$, hence in 7 there are $7 \times \frac{8}{8} = \frac{56}{8}$; $\frac{56}{8}$ plus the $\frac{7}{8}$ of the mixed number $= \frac{56}{8} + \frac{7}{8} = \frac{63}{8}$, which is the required improper fraction.

$$13\frac{5}{16} = \frac{(13 \times 16) + 5}{16} = \frac{213}{16};\ 10\frac{3}{4} = \frac{(10 \times 4) + 3}{4} = \frac{43}{4}.$$

(36) The value of a fraction is obtained by dividing the numerator by the denominator.

To obtain the value of the fraction $\frac{13}{2}$ we divide the numerator 13 by the denominator 2. 2 is contained in 13 six times, with 1 remaining. This 1 remaining is written over the denominator 2, thereby making the fraction $\frac{1}{2}$, which is annexed to the whole number 6, and we obtain $6\frac{1}{2}$ as the mixed number. The reason for performing this operation is the following: In 1 there are $\frac{2}{2}$ (two halves), and in $\frac{13}{2}$ (thirteen halves) there are as many units (1) as 2 is contained times in 13, which is 6, and $\frac{1}{2}$ (one-half) unit remaining. Hence, $\frac{13}{12} = 6 + \frac{1}{2} = 6\frac{1}{2}$, the required mixed number. Ans. $\frac{17}{4} = 4\frac{1}{4}$. Ans. $\frac{69}{16} = 4\frac{5}{16}$. Ans. $\frac{16}{8} = 2$. Ans. $\frac{67}{64} = 1\frac{3}{64}$. Ans.

(37) In division of fractions, *invert the divisor* (or, in other words, turn it upside down) *and proceed as in multiplication.*

(*a*) $35 \div \frac{5}{16} = \frac{35}{1} \times \frac{16}{5} = \frac{35 \times 16}{1 \times 5} = \frac{560}{5} = 112.$ Ans.

(*b*) $\frac{9}{16} \div 3 = \frac{9}{16} \div \frac{3}{1} = \frac{9}{16} \times \frac{1}{3} = \frac{9 \times 1}{16 \times 3} = \frac{9}{48} = \frac{3}{16}.$ Ans.

(*c*) $\frac{17}{2} \div 9 = \frac{17}{2} \div \frac{9}{1} = \frac{17}{2} \times \frac{1}{9} = \frac{17 \times 1}{2 \times 9} = \frac{17}{18}.$ Ans.

(*d*) $\frac{113}{64} \div \frac{7}{16} = \frac{113}{64} \times \frac{16}{7} = \frac{113 \times 16}{64 \times 7} = \frac{1,808}{448} = \frac{452}{112} = \frac{113}{28}$

$$\begin{array}{r} 28)\,113\,(4\frac{1}{28}. \text{ Ans.} \\ 112 \\ \hline 1 \end{array}$$

(*e*) $15\frac{3}{4} \div 4\frac{3}{8} = ?$ Before proceeding with the division, reduce both of the mixed numbers to improper fractions. Thus, $15\frac{3}{4} = \frac{(15 \times 4) + 3}{4} = \frac{60 + 3}{4} = \frac{63}{4}$, and $4\frac{3}{8} = \frac{(4 \times 8) + 3}{8} = \frac{32 + 3}{8} = \frac{35}{8}$. The problem is now $\frac{63}{4} \div \frac{35}{8} = ?$ As before, invert the divisor and multiply; $\frac{63}{4} \div \frac{35}{8} = \frac{63}{4} \times \frac{8}{35} = \frac{63 \times 8}{4 \times 35} = \frac{504}{140} = \frac{252}{70} = \frac{126}{35} = \frac{18}{5}$.

$$\begin{array}{l} 5)\,18\,(3\frac{3}{5} \quad \text{Ans.} \\ \;\;\underline{15} \\ \;\;\;\;3 \end{array}$$

(Above the divisor: $\frac{18}{5}$.)

(38) $\frac{1}{8} + \frac{2}{8} + \frac{5}{8} = \frac{1 + 2 + 5}{8} = \frac{8}{8} = 1.$ Ans.

When the *denominators* of the fractions to be added *are alike*, we know that the units are divided into the *same number of parts* (in this case *eighths*); we, therefore, *add the numerators* of the fractions to find the number of parts (eighths) taken or considered, thereby obtaining $\frac{8}{8}$ or 1 as the sum.

(39) When the *denominators* are *not alike* we know that the units are divided into *unequal parts*, so before adding them we must find a common denominator for the denominators of all the fractions. Reduce the fractions to fractions having this common denominator, add the numerators and write the sum over the common denominator.

In this case, the least common denominator, or the least number that will contain all the denominators, is 16; hence, we must reduce all these fractions to sixteenths and then add their numerators.

$\frac{1}{4} + \frac{3}{8} + \frac{5}{16} = ?$ To reduce the fraction $\frac{1}{4}$ to a fraction having 16 for a denominator, we must multiply both terms

of the fraction by some number which will make the denominator 16. This number evidently is 4, hence, $\frac{1 \times 4}{4 \times 4} = \frac{4}{16}$.

Similarly, both terms of the fraction $\frac{3}{8}$ must be multiplied by 2 to make the denominator 16, and we have $\frac{3 \times 2}{8 \times 2} = \frac{6}{16}$. The fractions now have a common denominator 16; hence, we find their sum by adding the numerators and placing their sum over the common denominator, thus: $\frac{4}{16} + \frac{6}{16} + \frac{5}{16} = \frac{4 + 6 + 5}{16} = \frac{15}{16}$. Ans.

(40) When mixed numbers and whole numbers are to be added, add the fractional parts of the mixed numbers separately, and if the resulting fraction is an improper fraction, reduce it to a whole or mixed number. Next, add all the whole numbers, including the one obtained from the addition of the fractional parts, and annex to their sum the fraction of the mixed number obtained from reducing the improper fraction.

$42 + 31\frac{5}{8} + 9\frac{7}{16} = ?$ Reducing $\frac{5}{8}$ to a fraction having a denominator of 16, we have $\frac{5}{8} \times \frac{2}{2} = \frac{10}{16}$. Adding the two fractional parts of the mixed numbers we have $\frac{10}{16} + \frac{7}{16} = \frac{10 + 7}{16} = \frac{17}{16} = 1\frac{1}{16}$.

The problem now becomes $42 + 31 + 9 + 1\frac{1}{16} = ?$

$$\begin{array}{r} 42 \\ 31 \\ 9 \\ 1\frac{1}{16} \\ \hline 83\frac{1}{16} \end{array} \text{ Ans.}$$

Adding all the whole numbers and the number obtained from adding the fractional parts of the mixed numbers, we obtain $83\frac{1}{16}$ as their sum.

(41) $29\frac{3}{4}+50\frac{5}{8}+41+69\frac{3}{16}=?$ $\frac{3}{4}=\frac{3\times 4}{4\times 4}=\frac{12}{16}$.

$\frac{5}{8}=\frac{5\times 2}{8\times 2}=\frac{10}{16}$. $\frac{12}{16}+\frac{10}{16}+\frac{3}{16}=\frac{12+10+3}{16}=\frac{25}{16}=1\frac{9}{16}$.

The problem now becomes $29+50+41+69+1\frac{9}{16}=?$

$$\begin{array}{rl} 29 & \text{square inches.} \\ 50 & \text{square inches.} \\ 41 & \text{square inches.} \\ 69 & \text{square inches.} \\ 1\frac{9}{16} & \text{square inches.} \\ \hline 190\frac{9}{16} & \text{square inches. Ans.} \end{array}$$

(42) (*a*) $\dfrac{7}{\frac{3}{16}}=7\div\frac{3}{16}=7\times\frac{16}{3}=\frac{7\times 16}{3}=\frac{112}{3}=37\frac{1}{3}$. Ans.

The line between 7 and $\frac{3}{16}$ means that 7 is to be divided by $\frac{3}{16}$.

(*b*) $\dfrac{\frac{15}{32}}{\frac{5}{8}}=\frac{15}{32}\div\frac{5}{8}=\frac{15}{32}\times\frac{8}{5}=\dfrac{\overset{3}{\cancel{15}}\times\cancel{8}}{\underset{4}{\cancel{32}}\times\cancel{5}}=\frac{3}{4}$. Ans.

(*c*) $\dfrac{\frac{4+3}{2+6}}{5}=\dfrac{\frac{7}{8}}{5}=\frac{7}{8\times 5}=\frac{7}{40}$. (See Art. **131.**) Ans.

(43) $\frac{7}{8}$ = value of the fraction, and 28 = the numerator. We find that 4 multiplied by $7=28$, so multiplying 8, the denominator of the fraction, by 4, we have 32 for the required denominator, and $\frac{28}{32}=\frac{7}{8}$. Hence, 32 is the required denominator. Ans.

(44) (*a*) $\frac{7}{8}-\frac{7}{16}=?$ When the *denominators* of fractions are *not alike* it is evident that the units are divided into *unequal parts*, therefore, before subtracting, *reduce the*

fractions to fractions having a common denominator. Then, *subtract the numerators, and place the remainder over the common denominator.*

$$\frac{7 \times 2}{8 \times 2} = \frac{14}{16}. \quad \frac{14}{16} - \frac{7}{16} = \frac{14-7}{16} = \frac{7}{16}. \quad \text{Ans.}$$

(*b*) $13 - 7\frac{7}{16} = ?$ This problem may be solved in two ways:

First: $13 = 12\frac{16}{16}$, since $\frac{16}{16} = 1$, and $12\frac{16}{16} = 12 + \frac{16}{16} = 12 + 1 = 13.$

$$\begin{array}{r} 12\frac{16}{16} \\ 7\frac{7}{16} \\ \hline 5\frac{9}{16} \end{array}$$

We can now subtract the whole numbers separately, and the fractions separately, and obtain $12 - 7 = 5$ and $\frac{16}{16} - \frac{7}{16} = \frac{16-7}{16} = \frac{9}{16}$. $5 + \frac{9}{16} = 5\frac{9}{16}$. Ans.

Second: By reducing both numbers to improper fractions having a denominator of 16.

$13 = \frac{13}{1} = \frac{13 \times 16}{1 \times 16} = \frac{208}{16}$. $7\frac{7}{16} = \frac{(7 \times 16) + 7}{16} = \frac{112 + 7}{16} = \frac{119}{16}$.

Subtracting, we have $\frac{208}{16} - \frac{119}{16} = \frac{208 - 119}{16} = \frac{89}{16}$ and

$$\frac{89}{16} = 16\overline{)89}(5\tfrac{9}{16} \qquad \begin{array}{r} 80 \\ \hline 9 \\ \hline 16 \end{array}$$

the same result that was obtained by the first method.

(*c*) $312\frac{9}{16} - 229\frac{5}{32} = ?$ We first reduce the fractions of the two mixed numbers to fractions having a common denominator. Doing this we have $\frac{9}{16} = \frac{9 \times 2}{16 \times 2} = \frac{18}{32}$. We can now subtract the whole numbers and fractions separately, and have $312 - 229 = 83$ and $\frac{18}{32} - \frac{5}{32} = \frac{18-5}{32} = \frac{13}{32}$.

$$\begin{array}{r} 312\frac{18}{32} \\ 229\frac{5}{32} \\ \hline 83\frac{13}{32} \end{array} \quad 83 + \frac{13}{32} = 83\frac{13}{32}. \quad \text{Ans.}$$

(45) The man evidently traveled $85\frac{5}{12}+78\frac{9}{15}+125\frac{17}{35}$ miles.

Adding the fractions separately in this case,

$$\frac{5}{12}+\frac{9}{15}+\frac{17}{35}=\frac{5}{12}+\frac{3}{5}+\frac{17}{35}=\frac{175+252+204}{420}=\frac{631}{420}=1\frac{211}{420}.$$

Adding the whole numbers and the mixed number representing the sum of the fractions, the sum is $289\frac{211}{420}$ miles. Ans

$$\begin{array}{r} 85 \\ 78 \\ 125 \\ 1\frac{211}{420} \\ \hline 289\frac{211}{420} \end{array}$$

To find the least common denominator, we have

$$\begin{array}{r|l} 5 & 12,\ 5,\ 35 \\ \hline 7 & 12,\ 1,\ 7 \\ \hline & 12,\ 1,\ 1, \end{array} \text{ or } 5\times7\times12=420.$$

(46)

$$\begin{array}{lll} & 573\frac{4}{5} \text{ tons.} & \frac{4}{5}=\frac{32}{40} \\ & 216\frac{5}{8} \text{ tons.} & \frac{5}{8}=\frac{25}{40} \\ \hline \textit{difference} & 357\frac{7}{40} \text{ tons. Ans.} & \frac{7}{40}=\textit{difference.} \end{array}$$

(47) Reducing $9\frac{1}{4}$ to an improper fraction, it becomes $\frac{37}{4}$. Multiplying $\frac{37}{4}$ by $\frac{3}{8}$, $\frac{37}{4}\times\frac{3}{8}=\frac{111}{32}=3\frac{15}{32}$ dollars. Ans.

(48) Referring to Arts. **114** and **116,**

$\frac{2}{3}$ of $\frac{3}{4}$ of $\frac{7}{11}$ of $\frac{19}{20}$ of 11 multiplied by $\frac{7}{8}$ of $\frac{5}{6}$ of 45 =

$$\frac{\cancel{2}\times\cancel{3}\times7\times19\times\cancel{11}\times7\times5\times\overset{\overset{3}{\cancel{15}}}{\cancel{45}}}{\cancel{3}\times4\times\cancel{11}\times\underset{4}{\cancel{20}}\times1\times8\times\underset{\cancel{3}}{\cancel{6}}\times1}=\frac{7\times19\times7\times5\times3}{4\times4\times8}=\frac{13{,}965}{128}=$$

$109\frac{13}{128}$. Ans.

(49) $\frac{3}{4}$ of $16=\frac{3}{\cancel{4}}\times\frac{\overset{4}{\cancel{16}}}{1}=12.\quad 12\div\frac{2}{3}=\frac{\overset{6}{\cancel{12}}}{1}\times\frac{3}{\cancel{2}}=18.$ Ans.

(50) $211\frac{1}{4}\times1\frac{7}{8}=\frac{845}{4}\times\frac{15}{8}$, reducing the mixed numbers

to improper fractions. $\frac{845}{4} \times \frac{15}{8} = \frac{12,675}{32}$ cents = amount paid for the lead. The number of pounds sold is evidently $\frac{12,675}{32} \div 2\frac{1}{2} = \frac{\overset{2,535}{\cancel{12,675}}}{\underset{16}{\cancel{32}}} \times \frac{\cancel{2}}{\cancel{5}} = \frac{2,535}{16} = 158\frac{7}{16}$ pounds. The amount remaining is $211\frac{1}{4} - 158\frac{7}{16} = \frac{845}{4} - \frac{2,535}{16} = \frac{3,380}{16} - \frac{2,535}{16} = \frac{845}{16} = 52\frac{13}{16}$ pounds. Ans.

		tenths.	hundredths.	
(51)	.	0	8	= *Eight* **hundredths.**

	tenths.	hundredths.	thousandths.	
.	1	3	1	= *One hundred thirty-one* **thousandths.**

	tenths.	hundredths.	thousandths.	ten-thousandths.	
.	0	0	0	1	= *One* **ten-thousandth.**

	tenths.	hundredths.	thousandths.	ten-thousandths.	hundred-thousandths.	millionths.	
.	0	0	0	0	2	7	= *Twenty-seven* **millionths.**

	tenths.	hundredths.	thousandths.	ten-thousandths.	
.	0	1	0	8	= *One hundred eight* **ten-thousandths.**

	tenths.	hundredths.	thousandths.	ten-thousandths.	
93.	0	1	0	1	= Ninety-three, and *one hundred one* **ten-thousandths.**

In reading decimals, read the number just as you would if there were no ciphers before it. Then count from the decimal point towards the right, beginning with tenths, to as many places as there are figures, and the *name* of the last figure must be annexed to the previous reading of the figures to give the decimal reading. Thus, in the first example above, the simple reading of the figure is *eight*, and the name of its position in the decimal scale is **hundredths,** so that the decimal reading is *eight* **hundredths.** Similarly, the figures in the fourth example are ordinarily read *twenty-seven ;* the name of the position of the figure 7 in the decimal scale is **millionths,** giving, therefore, the decimal reading as *twenty-seven* **millionths.**

If there should be a whole number before the decimal point, read it as you would read any whole number, and read the decimal as you would if the whole number were not there; or, read the whole number and then say, "and" so many hundredths, thousandths, or whatever it may be, as "ninety-three, *and* one hundred one ten thousandths."

(52) See Art. **139.**

(53) See Art. **153.**

(54) See Art. **160.**

(55) A fraction is one or more of the equal parts of a unit, and is expressed by a numerator and a denominator, while a decimal fraction is a number of *tenths*, *hundredths*, *thousandths*, etc., of a unit, and is expressed by placing a period (.), called a decimal point, to the left of the figures of the number, and omitting the denominator.

(56) See Art. **165.**

(57) To reduce the fraction $\frac{1}{2}$ to a decimal, we annex one cipher to the numerator, which makes it 1.0. Dividing 1.0, the numerator, by 2, the denominator, gives a quotient of .5, the decimal point being placed before the *one* figure of the quotient, or .5, since only *one* cipher was annexed to the numerator. Ans.

$$\frac{7}{8}\quad 8\,)\,7.000 \qquad .875 \text{ Ans.}$$

$$\frac{5}{32}\quad 32\,)\,5.00000\,(.15625 \text{ Ans.}$$

$$\begin{array}{r} 32 \\ \hline 180 \\ 160 \\ \hline 200 \\ 192 \\ \hline 80 \\ 64 \\ \hline 160 \\ 160 \\ \hline \end{array}$$

$$\frac{125}{1000} = .125. \text{ Ans.}$$

Since $.65 = \frac{65}{100}$, then, $\frac{65}{100}$ must equal .65. Or, when the denominator is 10, 100, 1000, etc., point off as many places in the numerator as there are ciphers in the denominator. Doing so, $\frac{65}{100} = .65$. Ans.

(58) (*a*) This example, written in the form of a fraction, means that the numerator $(32.5 + .29 + 1.5)$ is to be divided by the denominator $(4.7 + 9)$. The operation is as follows:

$$\frac{32.5 + .29 + 1.5}{4.7 + 9} = ?$$

$$\begin{array}{r} 32.5 \\ +\ \ .29 \\ +\ 1.5 \\ \hline 13.7\,)\,34.29000\,(\,2.5029 \text{ Ans.} \\ 274 \\ \hline 689 \\ 685 \\ \hline 400 \\ 274 \\ \hline 1260 \\ 1233 \\ \hline 27 \end{array}$$

$$\begin{array}{r} 4.7 \\ +\ 9.0 \\ \hline 13.7 \end{array}$$

Since there are 5 decimal places in the dividend and 1 in the divisor, there are 5 − 1 or 4 places to be pointed off in the quotient. The fifth figure of the decimal is evidently less than 5.

(*b*) Here again the problem is to divide the numerator, which is $(1.283 \times \overline{8+5})$, by the denominator, which is 2.63. The operation is as follows:

$$\frac{1.283 \times \overline{8+5}}{2.63} = ? \qquad \overline{8+5} = 13.$$

$$\begin{array}{r}
1.283 \\
\times \quad 13 \\
\hline
3849 \\
1283
\end{array}$$

$$\begin{array}{l}
2.63)\overline{16.679000}(6.3418 \quad \text{Ans.} \\
\underline{1578} \\
899 \\
\underline{789} \\
1100 \\
\underline{1052} \\
480
\end{array}
\qquad
\begin{array}{r}
480 \\
\underline{263} \\
2170 \\
\underline{2104} \\
66
\end{array}$$

(*c*) $$\frac{\overline{589+27} \times \overline{163-8}}{25+39} = ?$$

$$\begin{array}{r}
163 \\
- \quad 8 \\
\hline
155 \\
\times\, 616 \\
\hline
930 \\
155 \\
930
\end{array}$$

$$\begin{array}{r}
589 \\
+\ 27 \\
\hline
616
\end{array}$$

$$\begin{array}{l}
64)\overline{95480.000}(1491.875 \quad \text{Ans.} \\
\underline{64} \\
314 \\
\underline{256} \\
588 \\
\underline{576} \\
120 \\
\underline{64} \\
560 \\
\underline{512} \\
480 \\
\underline{448} \\
320 \\
\underline{320}
\end{array}$$

$$\begin{array}{r}
25 \\
+39 \\
\hline
64
\end{array}$$

There are three decimal places in the quotient, since three ciphers were annexed to the dividend.

(*d*) $\frac{\overline{40.6+7.1} \times (3.029-1.874)}{6.27+8.53-8.01} = ?$

$$\begin{array}{r} 40.6 \\ +\ \ 7.1 \\ \hline 47.7 \end{array} \qquad \begin{array}{r} 3.029 \\ -\ 1.874 \\ \hline 1.155 \\ \times\ \ 47.7 \\ \hline 8085 \\ 8085 \\ 4620 \\ \hline 55.0935 \end{array}$$

$$\begin{array}{r} 6.27 \\ +\ 8.53 \\ \hline 14.80 \\ -\ 8.01 \\ \hline 6.79 \end{array}$$

$$6.79\overline{)55.093500}(8.1139. \quad \text{Ans.}$$

$$\begin{array}{r} 55.093500 \\ 5432 \\ \hline 773 \\ 679 \\ \hline 945 \\ 679 \\ \hline 2660 \\ 2037 \\ \hline 6230 \\ 6111 \\ \hline 119 \end{array}$$

6 decimal places in the dividend — 2 decimal places in the divisor = 4 decimal places to be pointed off in the quotient.

(59) $.875 = \frac{875}{1{,}000} = \frac{175}{200} = \frac{7}{8}$ of a foot.

1 foot = 12 inches.

$\frac{7}{8}$ of 1 foot $= \frac{7}{\cancel{8}_{2}} \times \frac{\cancel{12}^{3}}{1} = \frac{21}{2} = 10\frac{1}{2}$ inches. Ans.

(60) 12 inches = 1 foot.

$\frac{3}{16}$ of an inch $= \frac{3}{16} \div 12 = \frac{\cancel{3}}{16} \times \frac{1}{\cancel{12}_{4}} = \frac{1}{64}$ of a foot.

Point off 6 decimal places in the quotient, since we annexed six ciphers to the dividend, the divisor containing no decimal places; hence, 6 — 0 = 6 places to be pointed off.

```
 1
64 ) 1.000000 ( .015625  Ans.
     64
     ---
     360
     320
     ---
      400
      384
      ---
       160
       128
       ---
        320
        320
        ---
```

(61) If 1 cubic inch of water weighs .03617 of a pound, the weight of 1,500 cubic inches will be .03617 × 1,500 = 54.255 lb.

```
 .03617 lb.
   1500
-------
1808500
3617
-------
54.25500 lb.  Ans.
```

(62) 72.6 feet of fencing at \$.50 a foot would cost

```
   72.6 × .50, or $36.30.
    .50
-------
$36.300
```

If, by selling a carload of coal at a profit of \$1.65 per ton, I make \$36.30, then there must be as many tons of coal in the car as 1.65 is contained times in 36.30, or 22 tons.

```
1.65 ) 36.30 ( 22 tons.  Ans.
       330
       ---
        330
        330
        ---
```

(63) 231) 17892.00000 (77.45454, or 77.4545 to four decimal places. Ans.

```
231 ) 17892.00000 ( 77.45454
      1617
       1722
       1617
        1050
         924
         1260
         1155
          1050
           924
           1260
           1155
            1050
```

(64)
$$\frac{\overset{37.13}{\cancel{74.26}} \times \overset{\cancel{2}}{\cancel{24}} \times \overset{.0952}{\cancel{3.1416}} \times 19 \times 19 \times 350}{\underset{1,000}{\cancel{33,000}} \times \underset{\cancel{2}}{\cancel{12}} \times \cancel{4}} =$$

$$\frac{37.13 \times .0952 \times 19 \times 19 \times 350}{1,000} = \frac{446,618.947600}{1,000} =$$

446.619 to three decimal places. Ans.

```
   37.13        19        361        3.534776
   .0952        19        350          126350
   -----        ---      -----      ----------
    7426       171      18050       176738800
  18565        19      1083        10604328
 33417         ---     ------     21208656
 --------      361     126350     7069552
 3.534776                        3534776
                                 --------------
                                 446618.947600
```

(65) See Art. **174.** Applying rule in Art. **175,**

(*a*) $.7928 \times \frac{64}{64} = \frac{50.7392}{64} = \frac{51}{64}$. Ans.

(*b*) $.1416 \times \frac{32}{32} = \frac{4.5312}{32} = \frac{5}{32}$. Ans.

(*c*) $.47915 \times \frac{16}{16} = \frac{7.6664}{16} = \frac{8}{16} = \frac{1}{2}$. Ans.

(66) In subtraction of decimals, *place the decimal points directly under each other*, and proceed as in the subtraction of whole numbers, placing the *decimal point in the remainder directly under the decimal points above.*

$$(a)\quad \begin{array}{r} 709.6300 \\ .8514 \\ \hline 708.7786 \end{array} \text{ Ans.}$$

In the above example we proceed as follows: We can not subtract 4 ten-thousandths from 0 ten-thousandths, and, as there are no thousandths, we take 1 hundredth from the three hundredths. 1 *hundredth* = 10 *thousandths* = 100 *ten-thousandths*. 4 ten-thousandths from 100 ten-thousandths leaves 96 ten-thousandths. 96 ten-thousandths = 9 *thousandths* + 6 *ten-thousandths*. Write the 6 ten-thousandths in the ten-thousandths place in the remainder. The next figure in the subtrahend is 1 thousandth. This must be subtracted from the 9 thousandths which is a part of the 1 hundredth taken previously from the 3 hundredths. Subtracting, we have 1 thousandth from 9 thousandths leaves 8 thousandths, the 8 being written in its place in the remainder. Next we have to subtract 5 hundredths from 2 hundredths (1 hundredth having been taken from the 3 hundredths makes it but 2 hundredths now). Since we can not do this, we take 1 tenth from 6 tenths. 1 tenth (= 10 hundredths) + 2 hundredths = 12 hundredths. 5 hundredths from 12 hundredths leaves 7 hundredths. Write the 7 in the hundredths place in the remainder. Next we have to subtract 8 tenths from 5 tenths (5 tenths now, because 1 tenth was taken from the 6 tenths). Since this can not be done, we take 1 unit from the 9 units. 1 *unit* = 10 *tenths*; 10 tenths + 5 tenths = 15 tenths, and 8 tenths from 15 tenths leaves 7 tenths. Write the 7 in the tenths place in the remainder. In the minuend we now have 708 units (one unit having been taken away) and 0 units in the subtrahend. 0 units from 708 units leaves 708 units; hence, we write 708 in the remainder.

$$(b)\quad \begin{array}{r} 81.963 \\ 1.700 \\ \hline 80.263 \end{array} \text{ Ans.} \qquad (c)\quad \begin{array}{r} 18.00 \\ .18 \\ \hline 17.82 \end{array} \text{ Ans.} \qquad (d)\quad \begin{array}{r} 1.000 \\ .001 \\ \hline .999 \end{array} \text{ Ans.}$$

(*e*) $872.1 - (.8721 + .008) = ?$ In this problem we are to subtract $(.8721 + .008)$ from 872.1. First perform the operation as indicated by the sign between the decimals enclosed by the parenthesis.

$$\begin{array}{r} .8721 \\ .008 \\ \hline .8801 \end{array} \textit{ sum.}$$

Subtracting the sum (obtained by adding the decimals enclosed within the parenthesis) from the number 872.1 (as required by the minus sign before the parenthesis), we obtain the required remainder.

$$\begin{array}{r} 872.1000 \\ .8801 \\ \hline 871.2199 \end{array} \text{ Ans.}$$

(*f*) $(5.028 + .0073) - (6.704 - 2.38) = ?$ First perform the operations as indicated by the signs between the numbers enclosed by the parentheses. The first parenthesis shows that 5.028 and .0073 are to be added. This gives 5.0353 as their sum.

$$\begin{array}{r} 5.0280 \\ .0073 \\ \hline 5.0353 \end{array} \textit{ sum.}$$

The second parenthesis shows that 2.38 is to be subtracted from 6.704. The difference is found to be 4.324.

$$\begin{array}{r} 6.704 \\ 2.380 \\ \hline 4.324 \end{array} \textit{ difference.}$$

The sign between the parentheses indicates that the quantities obtained by performing the above operations, are to be subtracted, namely, that 4.324 is to be subtracted from 5.0353. Performing this operation we obtain .7113 as the final result.

$$\begin{array}{r} 5.0353 \\ 4.324 \\ \hline .7113 \end{array} \text{ Ans.}$$

(67) In subtracting a decimal from a fraction, or subtracting a fraction from a decimal, either reduce the fraction to a decimal before subtracting, or reduce the decimal to a fraction and then subtract.

(*a*) $\frac{7}{8} - .807 = ?$ $\frac{7}{8}$ reduced to a decimal becomes

$$\frac{7}{8}) \underline{7.000} \atop .875$$

Subtracting .807 from .875 the remainder is .068, as shown.

$$\begin{array}{r} .875 \\ .807 \\ \hline .068 \end{array} \text{ Ans.}$$

(*b*) $.875-\frac{3}{8}=?$ Reducing .875 to a fraction we have $.875=\frac{875}{1{,}000}=\frac{175}{200}=\frac{35}{40}=\frac{7}{8}$; hence, $\frac{7}{8}-\frac{3}{8}=\frac{7-3}{8}=\frac{4}{8}=\frac{1}{2}$. Ans.

Or, by reducing $\frac{3}{8}$ to a decimal, $\frac{3}{8}$) 3.000 and then sub-

.375

tracting, we obtain $.875-.375=.5=\frac{5}{10}=\frac{1}{2}$, the same answer as above.

$$\begin{array}{r} .875 \\ .375 \\ \hline .500 \end{array} \text{ Ans.}$$

(*c*) $\left(\frac{5}{32}+.435\right)-\left(\frac{21}{100}-.07\right)=?$ We first perform the operations as indicated by the signs between the numbers enclosed by the parentheses. Reduce $\frac{5}{32}$ to a decimal and we obtain $\frac{5}{32}=.15625$ (see example 57).

Adding .15625 and .435, $\begin{array}{r} .15625 \\ .435 \\ \hline \textit{sum}\ \ .59125 \end{array}$ $\frac{21}{100}=.21$; subtracting, $\begin{array}{r} .21 \\ .07 \\ \hline \textit{difference}\ \ .14 \end{array}$

We are now prepared to perform the operation indicated by the minus sign between the parentheses, which is,

$$\begin{array}{r} .59125 \\ .14 \\ \hline \textit{difference}\ \ .45125 \end{array} \text{ Ans.}$$

(*d*) This problem means that 33 millionths and 17 thousandths are to be added. Also, that 53 hundredths and 274 thousandths are to be added, and the smaller of these sums is to be subtracted from the larger sum. Thus, $(.53+.274)-(.000033+.017)=?$

tenths.	hundredths.	thousandths.	ten-thousandths.	hundred-thousandths.	millionths.	
.0	0	0	0	3	3	
.0	1	7				
.0	1	7	0	3	3	*sum.*

tenths.	hundredths.	thousandths.	
.5	3		
.2	7	4	
.8	0	4	*sum.*

$$\begin{array}{rl} & .804 \quad \textit{larger sum,} \\ & .017033 \quad \textit{smaller sum,} \\ \hline \textit{difference} & .786967 \quad \text{Ans.} \end{array}$$

(68) In addition of decimals the *decimal points must be placed directly under each other*, so that *tenths* will come *under tenths*, *hundredths under hundredths*, *thousandths under thousandths*, etc. The addition is then performed as in whole numbers, *the decimal point of the sum being placed directly under the decimal points above.*

```
 .125
 .7
 .089
 .4005
 .9
 .000027
 --------
2.214527   Ans.
```

(69)

```
  927.416
    8.274
  372.6
   62.07938
 -----------
 1370.36938   Ans.
```

(70)

tenths. hundredths. thousandths. ten-thousandths. hundred-thousandths. millionths.

```
.017
.2
.000047
--------
.217047 = Ans.
```

(71) (*a*)

```
   .107
   .013
   ----
    321
   107
 -------
.001391   Ans.
```

There are 3 decimal places in the multiplicand and 3 in the multiplier; hence, there are $3 + 3$ or 6 decimal places in the product. Since the product contains but four figures, we prefix two ciphers in order to obtain the necessary six decimal places.

(*b*)

```
      203
      2.03
      ----
      609
    4060
    ------
    412.09
      .203
   -------
   123627
  824180
  --------
  83.65427   Ans.
```

There are two decimal places in the multiplier and none in the multiplicand; hence, there are $2 + 0$ or two decimal places in the first product.

Since there are 2 decimal places in the multiplicand and 3 decimal places in the multiplier, there are $3 + 2$ or 5 decimal places in the second product.

(*c*) First perform the operations indicated by the signs between the numbers enclosed by the parenthesis, and then perform whatever may be required by the sign before the parenthesis.

Multiply together the numbers 2.7 and 31.85.

$$\begin{array}{r} 31.85 \\ 2.7 \\ \hline 22295 \\ 6370 \\ \hline 85.995 \end{array}$$

The parenthesis shows that .316 is to be taken from 3.16.

$$\begin{array}{r} 3.160 \\ .316 \\ \hline 2.844 \end{array}$$

The product obtained by the first operation is now multiplied by the remainder obtained by performing the operation indicated by the signs within the parenthesis.

$$\begin{array}{r} 85.995 \\ 2.844 \\ \hline 343980 \\ 343980 \\ 687960 \\ 171990 \\ \hline 244.569780 \end{array} \text{ Ans.}$$

(*d*) $(107.8 + 6.541 - 31.96) \times 1.742 = ?$

$$\begin{array}{r} 107.8 \\ +\quad 6.541 \\ \hline 114.341 \\ -\quad 31.96 \\ \hline 82.381 \\ \times\quad 1.742 \\ \hline 164762 \\ 329524 \\ 576667 \\ 82381 \\ \hline 143.507702 \end{array} \text{ Ans.}$$

(72) (*a*) $\left(\frac{7}{16} - .13\right) \times \overline{.625 + \frac{5}{8}} = ?$

First perform the operation indicated by the parenthesis.

$$\frac{7}{16}=16\overline{)\,7.0000}(.4375$$

$$\begin{array}{l} 64 \\ \hline \ \ 60 \\ \ \ 48 \\ \hline \ \ 120 \\ \ \ 112 \\ \hline \ \ \ \ 80 \\ \ \ \ \ 80 \\ \hline \end{array}$$

We point off four decimal places since we annexed four ciphers.

$$\begin{array}{r} .4375 \\ .13 \\ \hline .3075 \end{array}$$

Subtracting, we obtain .3075

The vinculum has the same meaning as the parenthesis; hence, we perform the operation indicated by it. We point off three decimal places, since three ciphers were annexed to the 5.

$$\frac{5}{8}=8\overline{)\,5.000}\quad .625$$

Adding the terms included by the vinculum, we obtain

$$\begin{array}{r} .625 \\ .625 \\ \hline 1.250 \end{array}$$

The final operation is to perform the work indicated by the sign between the parenthesis and the vinculum, thus,

$$\begin{array}{r} .3075 \\ 1.25 \\ \hline 15375 \\ 6150 \\ 3075 \\ \hline .384375 \end{array}\ \text{Ans.}$$

(*b*) $\left(\frac{19}{32}\times.21\right)-\left(.02\times\frac{3}{16}\right)=?$

$.21=\frac{21}{100}.\quad \frac{19}{32}\times\frac{21}{100}=\frac{399}{3200}.\quad .02=\frac{2}{100}.\quad \frac{2}{100}\times\frac{3}{16}=\frac{6}{1600}=\frac{3}{800}.$

$\frac{3}{800}=\frac{3\times4}{800\times4}=\frac{12}{3200}.\qquad \frac{399}{3200}-\frac{12}{3200}=\frac{399-12}{3200}=\frac{387}{3200}.$

Reducing $\frac{387}{3200}$ to a decimal, we obtain

$$\begin{array}{r|l}
\frac{387}{3200}\,)\ 387.0000000\ (.1209375 & \textbf{Ans.} \\
3200 & \\
\hline
6700 & \\
6400 & \\
\hline
30000 & \\
28800 & \\
\hline
12000 & \\
9600 & \\
\hline
24000 & \\
22400 & \\
\hline
16000 & \\
16000 & \\
\hline
\end{array}$$

Point off seven decimal places, since seven ciphers were annexed to the dividend.

(c) $\left(\frac{13}{4} + .013 - 2.17\right) \times \overline{13\frac{1}{4} - 7\frac{5}{16}} = ?$

$\frac{13}{4} = \frac{13}{4})\,13.00$
$\phantom{\frac{13}{4} = \frac{13}{4})\,1}3.25$

Point off two decimal places, since two ciphers were annexed to the dividend.

$$\begin{array}{r}
3.25 \\
+\ .013 \\
\hline
3.263 \\
-\ 2.17 \\
\hline
1.093
\end{array}$$

$\frac{5}{16}$ reduced to a decimal is .3125, since

$$\begin{array}{r}
\frac{5}{16}\,)\ 5.0000\ (.3125 \\
48 \\
\hline
20 \\
16 \\
\hline
40 \\
32 \\
\hline
80 \\
80 \\
\hline
\end{array}$$

Point off four decimal places, since four ciphers were annexed to the dividend.

Then, $7\frac{5}{16} = 7.3125$, and $13\frac{1}{4} = 13.25$, since $\frac{1}{4} = \frac{1}{4})\,\underline{1.00}$
$\ .25$

$$\begin{array}{r} 13.25 \\ -\ 7.3125 \\ \hline 5.9375 \end{array} \qquad \begin{array}{r} 5.9375 \\ \times\ 1.093 \\ \hline 178125 \\ 534375 \\ 593750 \\ \hline 6.4896875 \end{array} \text{ Ans.}$$

(73) (*a*) $.875 \div \frac{1}{2} = .875 \div .5 \left(\text{since } \frac{1}{2} = .5\right) = 1.75$. Ans.

Another way of solving this is to reduce .875 to its equivalent common fraction and then divide.

$.875 = \frac{7}{8}$, since $.875 = \frac{875}{1{,}000} = \frac{175}{200} = \frac{35}{40} = \frac{7}{8}$; then, $\frac{7}{8} \div \frac{1}{2} = \frac{7}{\cancel{8}_4} \times \frac{\cancel{2}}{1} = \frac{7}{4} = 1\frac{3}{4}$. Since $\frac{3}{4} = $

$$\begin{array}{r} 4)\,3.00\,(.75 \\ 28 \\ \hline 20 \\ 20 \\ \hline \end{array}$$

$1\frac{3}{4} = 1.75$, the same answer as above.

(*b*) $\frac{7}{8} \div .5 = \frac{7}{8} \div \frac{1}{2} \left(\text{since } .5 = \frac{1}{2}\right) = \frac{7}{\cancel{8}_4} \times \frac{\cancel{2}}{1} = \frac{7}{4} = 1\frac{3}{4}$, or 1.75. Ans.

This can also be solved by reducing $\frac{7}{8}$ to its equivalent decimal and dividing by .5; $\frac{7}{8} = .875$; $.875 \div .5 = 1.75$. Since there are three decimal places in the dividend and one in the divisor, there are $3 - 1$, or 2 decimal places in the quotient.

(*c*) $\frac{.375 \times \frac{1}{4}}{\frac{5}{16} - .125} = ?$ We shall solve this problem by first reducing the decimals to their equivalent common fractions.

$.375 = \frac{375}{1{,}000} = \frac{75}{200} = \frac{15}{40} = \frac{3}{8}$. $\frac{3}{8} \times \frac{1}{4} = \frac{3}{32}$, or the value of the numerator of the fraction.

$.125 = \frac{125}{1{,}000} = \frac{25}{200} = \frac{1}{8}$. Reducing $\frac{1}{8}$ to sixteenths, we have $\frac{1 \times 2}{8 \times 2} = \frac{2}{16}$. Then, $\frac{5}{16} - \frac{2}{16} = \frac{3}{16}$, or the value of the de-

nominator of the fraction. The problem is now reduced to

$$\frac{\frac{3}{32}}{\frac{3}{16}} = ?\quad \frac{\frac{3}{32}}{\frac{3}{16}} = \frac{3}{32} \div \frac{3}{16} = \frac{\cancel{3}}{\underset{2}{\cancel{32}}} \times \frac{\cancel{16}}{\cancel{3}} = \frac{1}{2} \text{ or } .5. \quad \text{Ans.}$$

(74) $\dfrac{1.25 \times 20 \times 3}{\dfrac{87 + (11 \times 8)}{459 + 32}} = ?$ In this problem $1.25 \times 20 \times 3$ constitutes the numerator of the complex fraction.

$$\begin{array}{r} 1.25 \\ \times \quad 20 \\ \hline 25.00 \\ \times \quad 3 \\ \hline 75 \end{array}$$

Multiplying the factors of the numerator together, we find their product to be 75.

The fraction $\dfrac{87 + (11 \times 8)}{459 + 32}$ constitutes the denominator of the complex fraction. The value of the numerator of this fraction equals $87 + 88 = 175$.

The numerator is combined as though it were written $87 + (11 \times 8)$, and its result is

$$\begin{array}{r} 11 \\ 8 \text{ times} \\ \hline 88 \\ +87 \\ \hline 175 \end{array}$$

The value of the denominator of this fraction is equal to $459 + 32 = 491$. The problem then becomes

$$\frac{75}{\frac{175}{491}} = \frac{75}{1} \div \frac{175}{491} = \frac{75}{1} \times \frac{491}{175} = \frac{\overset{3}{\cancel{75}} \times 491}{\underset{7}{\cancel{175}}} = \frac{1,473}{7} = 210\frac{3}{7}. \quad \text{Ans.}$$

(75) 1 plus $.001 = 1.001$. $.01$ plus $.000001 = .010001$. And $1.001 - .010001 =$

$$\begin{array}{r} 1.001 \\ .010001 \\ \hline .990999 \end{array} \quad \text{Ans.}$$

(76) Since Nos. 0000, 1, 5, 10, 14, and 17 of the American wire gauge are, respectively, .46, .2893, .1819, .1018, .064, and .045 in. thick, the sum of the thickness of plates representing these numbers = .46 in. + .2893 in. + .1819 in. + .1018 in. + .064 in. + .045 in. = 1.142 in. Ans.

.46	in.
.2893	in.
.1819	in.
.1018	in.
.064	in.
.045	in.
1.1420	in.

(77) Since the areas of 4 steam pipes are, respectively, 927.416 sq. ft., 8.274 sq. ft., 372.6 sq. ft., and 62.07938 sq. ft., the sum of these, or their total area, = 1,370.36938 sq. ft. Ans.

927.416	sq. ft.
8.274	sq. ft.
372.6	sq. ft.
62.07938	sq. ft.
1370.36938	sq. ft.

(78) We will first find the length of pipe in branches leading to the streets D and E. In D there are two branches of pipe each 618 yd. long; hence, the length of pipe in the branch leading to Street $D = 2 \times 618$ yd. = 1,236 yd. In like manner, we find the length of the pipe in branch leading to Street $E = 3 \times 723$ yd. = 2,169 yd.

Adding the length of pipe laid along the avenue to the lengths of the branches leading to the various streets A, B, C, D, and E gives the total length of the pipe, or 8,883 yd. Ans.

3,012	yd. along avenue.
875	yd. in branch leading to Street A.
630	yd. in branch leading to Street B.
961	yd. in branch leading to Street C.
1,236	yd. in branch leading to Street D.
2,169	yd. in branch leading to Street E.
8,883	yd. total length of pipe.

(79) (*a*) Since this pipe job is composed of pipes of various sizes, we will first find the amount of pipe required of each respective size.

187 ft. of 1-in. pipe were used in the cellar and 39 ft. of 1-in. pipe on the first floor of the building; hence, the total number of feet of 1-in. pipe used = 187 ft. + 39 ft. = 226 ft.

230 ft. of $\frac{3}{4}$-in. pipe were used in the cellar, 77 ft. of $\frac{3}{4}$-in. pipe on the first floor of the building, and 103 ft. of $\frac{3}{4}$-in. pipe on the second floor; hence, the total number of feet of $\frac{3}{4}$-in. pipe used = 230 ft. + 77 ft. + 103 ft. = 410 ft.

97 ft. of $\frac{1}{2}$-in. pipe were used in the cellar, 879 ft. of $\frac{1}{2}$-in. pipe on the first floor of the building, and 927 ft. of $\frac{1}{2}$-in. pipe on the second; hence, the total number of feet of $\frac{1}{2}$-in. pipe used = 97 ft. + 879 ft. + 927 ft. = 1,903 ft.

1,036 ft. of $\frac{3}{8}$-in. pipe were used on the first floor, and 2,193 ft. of $\frac{3}{8}$-in. pipe were used on the second floor; hence, the total number of feet of $\frac{3}{8}$-in. pipe used = 1,036 ft. + 2,193 ft. = 3,229 ft.

We will now consider the fittings used in this pipe job. Since 109 lb. of fittings were used in the cellar, 62 lb. on the first floor, and 27 lb. on the second floor, the total number of pounds of fittings used = 109 lb. + 62 lb. + 27 lb. = 198 lb.

(*b*) Since in this job 226 ft. of 1-in. pipe were used, 410 ft. of $\frac{3}{4}$-in. pipe, 1,903 ft. of $\frac{1}{2}$-in. pipe, and 3,229 ft. of $\frac{3}{8}$-in. pipe, the total number of feet of pipe used = 5,768 ft. Ans.

```
 226 ft.
 410 ft.
1903 ft.
3229 ft.
--------
5768 ft.
```

(80) Since 326 ft. of pipe are used on one floor of a building, 197 ft. on another floor, 173 ft. on another, and 304 ft. on another, we find that the total number of feet of pipe used on all floors of this building = 326 ft. + 197 ft. + 173 ft. + 304 ft. = 1,000 ft. Since 1,007 ft. of pipe were delivered at the building, and but 1,000 ft. were used, there remains unused 1,007 ft. − 1,000 ft. = 7 ft. Ans.

```
 326 ft.
 197 ft.
 173 ft.
 304 ft.
--------
1000 ft.
```

(81) Since there are 5 small water tanks whose capacities are 137, 629, 136, 819, and 31 gal., respectively, the total capacity of the small water tanks = 1,752 gal. As stated in the question, the capacity of the large tank used to replace the 5 smaller ones is 2,200 gallons. Hence, we find that replacing the 5 smaller tanks by the one large tank increases the tank capacity 448 gal., since 2,200 gal. − 1,752 gal. = 448 gal. Ans.

$$\begin{array}{r}137 \text{ gal.}\\ 629 \text{ gal.}\\ 136 \text{ gal.}\\ 819 \text{ gal.}\\ \underline{31 \text{ gal.}}\\ 1752 \text{ gal.}\end{array}$$

(82) The thickness of No. 0 gauge = .3248 in., and of No. 0000 gauge = .46; hence, the difference between the thickness of Nos. 0000 and 0 = .46 in. − .3248 in. = .1352 in. Ans.

The thickness of No. 00 gauge = .3648 in., and of No. 000 gauge = .4096 in.; hence, the difference between the thickness of Nos. 000 and 00 = .4096 in. − .3648 in. = .0448 in. Ans.

The thickness of No. 0 gauge = .3248 in., and of No. 00 gauge = .3648; hence, the thickness of Nos. 0 + 00 = .3248 in. + .3648 in. = .6896 in. Thickness of No. 0000 gauge = .46; hence, the difference between the thickness of Nos. 0 + 00 and 0000 = .6896 in. − .46 in. = .2296 in. Ans.

The thickness of Nos. 00 = .3648 in., of 0 = .3248 in., and of 000 = .4096 in.; hence the thickness of Nos. 00 + 0 + 000 = .3648 in. + .3248 in. + .4096 in. = 1.0992 in. Thickness of No. 0000 = .46 in. Hence, the difference between the thickness of Nos. 00 + 0 + 000 and 0000 = 1.0992 − .46 = .6392 in. Ans.

(83) (*a*) Since there are 5 wipe joints, each weighing $\frac{1}{2}$ of a pound, the weight of the 5 = $5 \times \frac{1}{2} = \frac{5}{2}$, or $2\frac{1}{2}$ pounds. Since these are made from a pot of solder containing 10 pounds, there remains $10 - 2\frac{1}{2} = 7\frac{1}{2}$ pounds of solder. However, 5 pounds of solder are added to $7\frac{1}{2}$ pounds, making $12\frac{1}{2}$ pounds. From this 10 more joints are made, their weight being $10 \times \frac{1}{2}$, or 5 pounds. Since there were $12\frac{1}{2}$

pounds of solder, and 5 pounds were used, there remained $12\frac{1}{2}$ pounds − 5 pounds, or $7\frac{1}{2}$ pounds. Ans.

(*b*) If the pot contains 16 pounds of solder, and 11 pounds more were added, there were in the pot 16 pounds + 11 pounds = 27 pounds. Since 24 joints were made from 27 pounds of solder, and there still remained 3 pounds of unused solder, it is evident that there were 24 pounds of solder used for the 24 joints, or that 1 pound of solder was used in each joint, assuming them to be of the same size and weight.

(84) (*a*) If a steam pump running with a uniform speed night and day makes 2 strokes in 1 second, in 1 minute, or 60 seconds, it would make 2 strokes × 60, or 120 strokes. In 1 hour, or 60 minutes, it would make 120 strokes × 60, or 7,200 strokes, and in 1 day, or 24 hours, it would make 7,200 strokes × 24, or 172,800 strokes.

$$\begin{array}{r} 7200 \\ 24 \\ \hline 28800 \\ 14400 \\ \hline 172800 \\ 7 \\ \hline 1209600 \end{array}$$

Since this steam pump makes 172,800 strokes in 1 day, in 1 week, or 7 days, it will make 172,800 × 7, or 1,209,600 strokes. Ans.

(*b*) If the steam pump under consideration discharges 1 gallon for every 2 strokes, or in every second, in 1 minute it would discharge 60 gallons, and in 1 hour it would discharge 60 gallons × 60 = 3,600 gallons. Since it discharges 3,600 gallons in 1 hour, in 1 day, or 24 hours, it would discharge 3,600 gallons × 24 = 86,400 gallons, and in 1 week, or 7 days, it would discharge 86,400 gallons × 7, or 604,800 gallons. Ans.

(85) If each line of pipe is 125 ft. long, then the length of 17 lines is 125 ft. × 17 = 2,125 ft.

$$\begin{array}{r} 125 \\ 17 \\ \hline 875 \\ 125 \\ \hline 2125 \text{ ft.} \end{array}$$

$$\begin{array}{r} 79 \text{ ft.} \\ \underline{35} \\ 395 \\ \underline{237} \\ 2765 \text{ ft.} \\ \underline{17} \\ 19355 \\ \underline{2765} \\ 47005 \text{ ft.} \\ \underline{2125 \text{ ft.}} \\ 49130 \text{ ft.} \end{array}$$

Since each line has 35 branches, and each branch is 79 ft. long, the length of the 35 branches is 79 ft. $\times$ 35 = 2,765 ft., and the length of the branches of the 17 lines = 2,765 ft. $\times$ 17 = 47,005 ft. Adding 2,125 ft. to 47,005 ft., we find that the total length of the pipe = 49,130 ft.

(86) (*a*) Since a quantity of scrap lead weighing 3,240 lb. was bought for $2\frac{1}{2}$ cents per pound, the price paid for the lead = $.02\frac{1}{2} \times 3,240 =$ \$81. Ans.

$$\begin{array}{r} \$0.025 \\ \underline{3240} \\ 000 \\ 100 \\ 50 \\ \underline{75} \\ \$81.000 \end{array}$$

(*b*) $\frac{1}{10}$ of the quantity bought ($\frac{1}{10}$ of 3,240 lb.) or 324 lb., was used for calking purposes, and the remainder (3,240 lb. − 324 lb.), or 2,916 lb., was melted into bars and sold at $3\frac{1}{2}$ cents per lb.; however, $\frac{1}{9}$ of the remainder ($\frac{1}{9}$ of 2,916), or 324 lb., was lost during the process of melting. There remained the difference between 2,916 lb. and 324 lb. = 2,592 lb., which was melted into bars and sold at $3\frac{1}{2}$ cents per lb. Hence, the amount received for the bars of lead = $2,592 \times .03\frac{1}{2} =$ \$90.72. Ans.

$$\begin{array}{r} 3240 \\ -\underline{324} \\ 2916 \end{array} \qquad \begin{array}{r} 2916 \\ -\underline{324} \\ 2592 \end{array} \qquad \begin{array}{r} \$0.035 \\ \underline{2592} \\ 70 \\ 315 \\ 175 \\ \underline{70} \\ \$90.720 \end{array}$$

(87) If the capacity of the tank is $143\frac{1}{2}$, or 143.5 gallons (since $\frac{1}{2} = .5$; $2\overline{)1.0}$; see rule, Art. **165**), and the
$$.5$$
capacity of the pail is $3\frac{1}{2}$, or 3.5 gallons, it will require as many pails of water to fill the tank as 3.5 is contained times in 143.5, or 41 pails. Ans.

```
3.5)143.5(41
     140
     ---
       35
       35
       --
```

(88) (*a*) If the capacity of a cistern is 11,857.5 gallons, and a family consumes $127\frac{1}{2}$, or 127.5 gallons, then it is evident that this supply will last the family as many days as 127.5 is contained times in 11,857.5, or 93 days. Ans.

```
127.5)11857.5(93
      11475
      -----
        3825
        3825
        ----
```

(*b*) If the cistern is but half filled, it will contain $\frac{1}{2}$ of 11,857.5 gallons, or 5,928.75 gallons. If a drought prevailed for 39 days, it is evident that no water was added to the cistern during this time, but during each of these 39 days, 127.5 gallons were consumed, and altogether there were consumed $127.5 \times 39 = 4{,}972.5$ gallons.

```
  127.5
     39
  -----
  11475
 3825
 ------
 4972.5
```

Since the cistern contained 5,928.75 gallons (being only $\frac{1}{2}$ filled), and 4,972.5 gallons were consumed during the 39 days' drought, there remained in the cistern 5,928.75 gallons — 4,972.5 gallons, or 956.25 gal. Ans.

```
  5928.75 gal.
- 4972.5  gal.
  -------
   956.25 gal.
```

(89) If there are 97 lengths of pipe, and each length measures 5 ft. $3\frac{1}{2}$ in., or $63\frac{1}{2}$ in. over all, the whole length of the pipe = $63\frac{1}{2}$ in. $\times$ 97 = 6,159$\frac{1}{2}$ in.

$$\begin{array}{r} 63\frac{1}{2}\text{ in.} \\ \underline{97\phantom{\text{ in.}}} \\ 441\phantom{\text{ in.}} \\ 567\phantom{0\text{ in.}} \\ \underline{48\frac{1}{2}\phantom{\text{ in.}}} \\ 6159\frac{1}{2}\text{ in.} \end{array}$$

If the sockets are 4 in. long, then the allowance to be made = 96 $\times$ 4 in. = 384 in.

$$\begin{array}{r} 6159\frac{1}{2}\text{ in.} \\ \underline{-384\phantom{\frac{1}{2}}\text{ in.}} \\ 5775\frac{1}{2}\text{ in.} \end{array}$$

The exact length of the 97 pieces of pipe = 6,159$\frac{1}{2}$ in. − 384 in. = 5,775$\frac{1}{2}$ in.

Reducing 5,775$\frac{1}{2}$ in. to feet by dividing by 12, we have 481 ft. $3\frac{1}{2}$ in. Ans.

$$\begin{array}{l} 12)5775\frac{1}{2}\text{ in.}(481\text{ ft. }3\frac{1}{2}\text{ in.} \\ \underline{48} \\ 97 \\ \underline{96} \\ 15 \\ \underline{12} \\ 3\frac{1}{2} \end{array}$$

(90) One cubic inch of lead weighs .41 lb.; hence, 97.15 cu. in. of lead will weigh 97.15 $\times$ .41 = 39.8315 lb.

$$\begin{array}{r} .41\text{ lb.} \\ \underline{97.15\phantom{\text{ lb.}}} \\ 205\phantom{\text{ lb.}} \\ 41\phantom{0\text{ lb.}} \\ 287\phantom{00\text{ lb.}} \\ \underline{369\phantom{000\text{ lb.}}} \\ 39.8315\text{ lb.} \end{array}$$

Since 1 cu. in. of cast iron weighs .26 of a pound, 107 cu. in. of cast iron will weigh 107 $\times$ .26 = 27.82 lb.

$$\begin{array}{r} .26\text{ lb.} \\ \underline{107\phantom{\text{ lb.}}} \\ 182\phantom{\text{ lb.}} \\ 000\phantom{0\text{ lb.}} \\ \underline{26\phantom{00\text{ lb.}}} \\ 27.82\phantom{\text{ lb.}} \end{array}$$

The difference in weight between 97.15 cu. in. of lead and 107 cu. in. of cast iron must equal 39.8315 lb. $-$ 27.82 lb. $=$ 12.0115 lb. Ans.

$$\begin{array}{r} 39.8315 \text{ lb.} \\ -\,27.82 \text{ lb.} \\ \hline 12.0115 \text{ lb.} \end{array}$$

(91) 6 inches $= \frac{6}{12}$ of a foot, since 12 inches $=$ 1 foot. 12 feet 6 inches $= 12\frac{6}{12} = 12\frac{1}{2}$ feet $= \frac{(12 \times 2) + 1}{2} = \frac{25}{2}$ feet.

If there are 7 pieces of pipe and each piece is $12\frac{1}{2}$ feet long, then the whole length of the pipe would be $\frac{25}{2} \times 7 = \frac{175}{2} = 87.5$ feet.

12 inches $=$ 1 foot. And $\frac{3}{4}$ inch $= \frac{3}{4} \div 12 = \frac{3}{4} \div \frac{12}{1} = \frac{\cancel{3}}{4} \times \frac{1}{\underset{4}{\cancel{12}}} = \frac{1}{16}$ of a foot to be allowed at each joint for screwing.

$\frac{1}{16}$ reduced to its equivalent decimal $=$ .0625 of a foot.

The first length screws into the tank $\frac{1}{16}$ or .0625 of a foot, thereby shortening the length of the pipe .0625 of a foot. The length of the pipe now equals 87.5 feet $-$ .0625 foot $=$ 87.4375 feet.

$$\begin{array}{r} 87.5 \text{ feet.} \\ -\quad .0625 \text{ feet.} \\ \hline 87.4375 \text{ feet.} \end{array}$$

The $\frac{3}{4}$ of an inch, or $\frac{1}{16}$ of a foot, allowed at each of the other 6 joints must be added to the length of the pipe since the different lengths are connected by unions which prevent the ends of the pipe from coming together, and, in this case, keep them $\frac{3}{4}''$ apart. Hence, we have $6 \times \frac{1}{16} = \frac{6}{16}$ or .375 of a foot for the 6 joints.

These 6 joints lengthen the pipe .375 of a foot; consequently, the water will be discharged at a distance of 87.4375 feet + .375 foot, or 87.8125 feet from the tank.

$$\begin{array}{rl} 87.4375 & \text{feet.} \\ + \quad .375 & \text{feet.} \\ \hline 87.8125 & \text{feet.} \quad \text{Ans.} \end{array}$$

ARITHMETIC.

(QUESTIONS 92–188.)

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(92) A certain per cent. of a number means so many hundredths of that number.

25% of 8,428 lb. means 25 hundredths of 8,428 lb. Hence, 25% of 8,428 lb. = .25 × 8,428 lb. = 2,107 lb. Ans.

(93) Here \$100 is the base and 1% = .01 is the rate. Then, .01 × \$100 = \$1. Ans.

(94) $\frac{1}{2}$% means one-half of one per cent. Since 1% is .01, $\frac{1}{2}$% is .005, for, $2\,\underline{).010}$ / $.005$. And .005 × \$35;000 = \$175. Ans.

(95) Here 50 is the base, 2 is the percentage, and it is required to find the rate. Applying rule, Art. **193,**

$$\text{rate} = \text{percentage} \div \text{base};$$
$$\text{rate} = 2 \div 50 = .04 \text{ or } 4\%. \quad \text{Ans.}$$

(96) By Art. **193,** rate = percentage ÷ base.*

As percentage = 10 and base = 10, we have rate = 10 ÷ 10 = 1 = 100%. Hence, 10 is 100% of 10. Ans.

(97) (*a*) Rate = percentage ÷ by base. Art. **193.**

As percentage = \$176.54 and base = \$2,522, we have

$$\text{rate} = 176.54 \div 2{,}522 = .07 = 7\%. \quad \text{Ans.}$$

$$2522\,\underline{)\,176.54}$$
$$.07$$

---

* Remember that an expression of this form means that the first term is to be *divided by* the second term. Thus, as above, it means percentage *divided by* base.

(*b*) Base = percentage ÷ rate. Art. **192.**

As percentage = 16.96 and rate = 8% = .08, we have

$$\text{base} = 16.96 \div .08 = 212. \quad \text{Ans.}$$

$$\begin{array}{r} .08\,)\,\underline{16.96} \\ 212 \end{array}$$

(*c*) Amount is the sum of the base and percentage; hence, the percentage = amount minus the base.

Amount = 216.7025 and base = 213.5; hence, percentage = 216.7025 − 213.5 = 3.2025.

Rate = percentage ÷ base. Art. **193.**

Therefore, rate = 3.5025 ÷ 213.5 = .015 = $1\frac{1}{2}$%. Ans.

$$\begin{array}{r l} 213.5\,)\,3.2025\,(\,.015 = 1\frac{1}{2}\% \\ \underline{2135} \\ 10675 \\ \underline{10675} \end{array}$$

(*d*) The difference is the remainder found by subtracting the percentage from the base; hence, base − the difference = the percentage. Base = 207 and difference = 201.825, hence percentage = 207 − 201.825 = 5.175.

Rate = percentage ÷ base. Art. **192.**

Therefore, rate = $5.175 \div 207 = .025 = .02\frac{1}{2} = 2\frac{1}{2}\%$. Ans.

$$\begin{array}{r l} 207\,)\,5.175\,(\,.025 \\ \underline{414} \\ 1035 \\ \underline{1035} \end{array}$$

(98) In this problem \$5,500 is the amount, since it equals what he paid for the farm + what he gained; 15% is the rate, and the cost (to be found) is the base. Applying rule, Art. **197,**

base = amount ÷ (1 + rate); hence,
base = \$5,500 ÷ (1 + .15) = \$4,782.61. Ans.

$$
\begin{array}{r}
1.15)5500.0000(4782.61 \\
\underline{460} \\
900 \\
\underline{805} \\
950 \\
\underline{920} \\
300 \\
\underline{230} \\
700 \\
\underline{690} \\
100 \\
\underline{115}
\end{array}
$$

The example can also be solved as follows: 100% = cost; if he gained 15%, then $100 + 15 = 115\% = \$5,500$, the selling price.

If $115\% = \$5,500$, $1\% = \frac{1}{115}$ of $\$5,500 = \$47.8261$, and 100%, or the cost, $= 100 \times \$47.8261 = \$4,782.61$. Ans.

(99)

$$
\begin{array}{lll}
24\ \% \text{ of } \$950 = .24 \ \times 950 = & \$228 \\
12\frac{1}{2}\% \text{ of } \$950 = .125 \times 950 = & 118.75 \\
\underline{17\ \%} \text{ of } \$950 = .17 \ \times 950 = & \underline{161.50} \\
53\frac{1}{2}\% \text{ of } \$950 & = \$508.25
\end{array}
$$

The total amount of his yearly expenses, then, is \$508.25, hence his savings are $\$950 - \$508.25 = \$441.75$. Ans.

Or, as above, $24\% + 12\frac{1}{2}\% + 17\% = 53\frac{1}{2}\%$, the total percentage of expenditures; hence, $100\% - 53\frac{1}{2}\% = 46\frac{1}{2}\%$ = per cent. saved. And $\$950 \times .465 = 441.75$ = his yearly savings. Ans.

(100) The percentage is 961.38, and the rate is $.37\frac{1}{2}$. By Art. **192,**

Base = percentage ÷ rate

$= 961.38 \div .375 = 2,563.68$, the number. Ans.

Another method of solving is the following:

If $37\frac{1}{2}\%$ of a number is 961.38, then $.37\frac{1}{2}$ times the number = 961.38 and the number = $961.38 \div .37\frac{1}{2}$, which, as above = 2,563.68. Ans.

```
.375)961.38000(2563.68
     750
     ----
     2113
     1875
     ----
      2388
      2250
      ----
       1380
       1125
       ----
        2550
        2250
        ----
         3000
         3000
         ----
```

(101) Here \$1,125 is 30% of some number; hence, \$1,125 = the percentage, 30% = the rate, and the required number is the base. Applying rule, Art. **192,**

Base = percentage ÷ rate = \$1,125 ÷ .30 = \$3,750.

Since \$3,750 is $\frac{3}{4}$ of the property, one of the fourths is $\frac{1}{3}$ of \$3,750 = \$1,250, and $\frac{4}{4}$ or the entire property, is 4 × \$1,250 = \$5,000. Ans.

(102) Here \$4,810 is the difference and 35% the rate. By Art. **198,**

Base = difference ÷ (1 − rate)
= \$4,810 ÷ (1 − .35) = \$4,810 ÷ .65 = \$7,400. Ans.

```
.65)4810.00(7400              1.00
    455                        .35
    ---                        ---
     260                       .65
     260
     ---
      00
```

Solution can also be effected as follows: 100% = the sum diminished by 35%, then (1 − .35) = .65, which is \$4,810.

If 65% = \$4,810, 1% = $\frac{1}{65}$ of 4,810 = \$74, and 100% = 100 × \$74 = \$7,400. Ans.

(103) In this example the sales on Monday amounted to \$197.55, which was $12\frac{1}{2}$% of the sales for the entire week; i. e., we have given the percentage, \$197.55, and the rate, $12\frac{1}{2}$%, and the required number (or the amount of sales for the week) equals the base. By Art. **192,**

Base = percentage ÷ rate = \$197.55 ÷ .125;

or,

```
.125)197.5500(1580.4  Ans.
     125
     ---
      725
      625
      ----
      1005
      1000
      ----
         500
         500
         ---
```

Therefore, base = \$1,580.40, which also equals the sales for the week.

(104) 16.5 miles = $12\frac{1}{2}$% of the entire length of the road. We wish to find the *entire* length.

16.5 miles is the percentage, $12\frac{1}{2}$% is the rate, and the entire length will be the base. By Art. **192,**

Base = percentage ÷ rate = 16 5 ÷ .$12\frac{1}{2}$.

```
.125)16.500(132 miles.  Ans.
     125
     ---
      400
      375
      ---
       250
       250
       ---
```

(105) Here we have given the difference, or $35, and the rate, or 60%, to find the base. We use the rule in Art. **198**,

$$\text{Base} = \text{difference} \div (1 - \text{rate})$$
$$= \$35 \div (1 - .60) = \$35 \div .40 = \$87.50. \quad \text{Ans.}$$

$$\begin{array}{r} .40)\,35.000\,(87.5 \\ 320 \\ \hline 300 \\ 280 \\ \hline 200 \\ 200 \\ \hline \end{array}$$

Or, 100% = whole debt; 100% − 60% = 40% = $35.

If 40% = $35, then $1\% = \frac{1}{40}$ of $\$35 = \frac{35}{40}$, and 100% = $\frac{35}{40} \times 100 = \$87.50$. Ans.

(106) 28 rd. 4 yd. 2 ft. 10 in. to inches.

$$\begin{array}{r} 28 \\ \times\ 5\tfrac{1}{2} \\ \hline 154 \\ +\ \ 4 \\ \hline 158 \text{ yards} \\ \times\ \ 3 \\ \hline 474 \\ +\ \ 2 \\ \hline 476 \text{ feet} \\ \times\ 12 \\ \hline 5712 \\ +\ 10 \\ \hline 5722 \text{ inches. Ans.} \end{array}$$

Since there are $5\frac{1}{2}$ yards in one rod, in 28 rods there are $28 \times 5\frac{1}{2}$ or 154 yards; 154 yards plus 4 yards = 158 yards. There are 3 feet in one yard; therefore, in 158 yards there are 3×158 or 474 feet; 474 feet + 2 feet = 476 feet. There are 12 inches in one foot, and in 476 feet there are 12×476 or 5,712 inches; 5,712 inches + 10 inches = 5,722 inches. Ans.

(107)

$$\begin{array}{r} 12\,\underline{)\,5722} \text{ inches.} \\ 3\,\underline{)\,476} + 10 \text{ inches.} \\ 5\tfrac{1}{2}\,\underline{)\,158} + 2 \text{ feet.} \\ 28 + 4 \text{ yards.} \end{array}$$

Ans. = 28 rd. 4 yd. 2 ft. 10 in.

EXPLANATION.—There are 12 inches in 1 foot; hence, in 5,722 inches there are as many feet as 12 is contained times in 5,722 inches, or 476 ft. and 10 inches remaining. Write these 10 inches as a remainder. There are 3 feet in 1 yard; hence, in 476 feet there are as many yards as 3 is contained times in 476 feet, or 158 yards and 2 feet remaining. There are $5\frac{1}{2}$ yards in one rod; hence, in 158 yards there are 28 rods and 4 yards remaining. Then, in 5,722 inches there are 28 rd. 4 yd. 2 ft. 10 in.

(108)

$$\begin{array}{rl} 5 & \text{weeks 3.5 days.} \\ \times\ 7 & \\ \hline 35 & \text{days in 5 weeks.} \\ +\ 3.5 & \\ \hline 38.5 & \text{days.} \end{array}$$

Then, we find how many seconds there are in 38.5 days.

$$\begin{array}{rl} 38.5 & \text{days} \\ \times\quad 24 & \text{hours in one day.} \\ \hline 1540 & \\ 770 & \\ \hline 924.0 & \text{hours in 38.5 days.} \\ \times\quad 60 & \text{minutes in one hour.} \\ \hline 55440 & \text{minutes in 38.5 days.} \\ \times\quad 60 & \text{seconds in one minute.} \\ \hline 3326400 & \text{seconds in 38.5 days. Ans.} \end{array}$$

(109) Since there are 24 gr. in 1 pwt., in 13,750 gr. there are as many pennyweights as 24 is contained times in 13,750, or 572 pwt. and 22 gr. remaining. Since there are 20 pwt. in 1 oz., in 572 pwt. there are as many ounces as 20 is contained times in 572, or 28 oz. and 12 pwt. remaining.

Since there are 12 oz. in 1 lb. (Troy), in 28 oz there are as many pounds as 12 is contained times in 28, or 2 lb. and 4 oz. remaining. We now have the pounds and ounces required by the problem; therefore, in 13,750 gr. there are 2 lb. 4 oz. 12 pwt. 22 gr.

$$\begin{array}{r|l}
24 & 13750 \text{ gr.} \\
\hline
20 & 572 \text{ pwt.} + 22 \text{ gr.} \\
\hline
12 & 28 \text{ oz.} + 12 \text{ pwt.} \\
\hline
 & 2 \text{ lb.} + 4 \text{ oz.}
\end{array}$$

Ans. = 2 lb. 4 oz. 12 pwt. 22 gr.

(110)

$$\begin{array}{r|l}
100 & 4763254 \text{ li.} \\
\hline
80 & 47632 + 54 \text{ li.} \\
\hline
 & 595 + 32 \text{ ch.}
\end{array}$$

Ans. = 595 mi. 32 ch. 54 li.

EXPLANATION.—There are 100 li. in one chain; hence, in 4,763,254 li. there are as many chains as 100 is contained times in 4,763,254 li., or 47,632 ch. and 54 li. remaining. Write the 54 li. as a remainder. There are 80 ch. in one mile; hence, in 47,632 ch. there are as many miles as 80 is contained times in 47,632 ch., or 595 miles and 32 ch. remaining. Then, in 4,763,254 li. there are 595 mi. 32 ch. 54 li.

(111)

$$\begin{array}{r|l}
1728 & 764325 \text{ cu. in.} \\
\hline
27 & 442 + 549 \text{ cu. in.} \\
\hline
 & 16 \text{ cu. yd.} + 10 \text{ cu. ft.}
\end{array}$$

Ans. = 16 cu. yd. 10 cu. ft. 549 cu. in.

EXPLANATION.—There are 1,728 cu. in. in one cubic foot; hence, in 764,325 cu. in. there are as many cubic feet as 1,728 is contained times in 764,325, or 442 cu. ft. and 549 cu. in. remaining. Write the 549 cu. in. as a remainder. There are 27 cu. ft. in one cubic yard; hence, in 442 cu. ft. there are as many cubic yards as 27 is contained times in 442 cu. ft., or 16 cu. yd. and 10 cu. ft. remaining. Then, in 764,325 cu. in. there are 16 cu. yd. 10 cu. ft. 549 cu. in.

(112) We must arrange the different terms in columns, taking care to have like denominations in the same column.

	rd.	yd.	ft.	in.	
	2	2	2	3	
		4	1	9	
			2	7	
	3	$2\frac{1}{2}$	0	7	
or	3	2	2	1	Ans.

EXPLANATION.—We begin to add at the right-hand column. $7 + 9 + 3 = 19$ in.; as 12 in. make one foot, 19 in. = 1 ft. and 7 in. Place the 7 in. in the inches column, and reserve the 1 ft. to add to the next column.

1 (reserved) $+ 2 + 1 + 2 = 6$ ft. Since 3 ft. make 1 yard, 6 ft. = 2 yd. and 0 ft. remaining. Place the cipher in the column of feet and reserve the 2 yd. for the next column.

2 (reserved) $+ 4 + 2 = 8$ yd. Since $5\frac{1}{2}$ yd. = 1 rod, 8 yd. = 1 rd. and $2\frac{1}{2}$ yd. Place $2\frac{1}{2}$ yd. in the yards column, and reserve 1 rd. for the next column; 1 (reserved) $+ 2 = 3$ rd.

Ans. =	3 rd.	$2\frac{1}{2}$ yd.	0 ft.	7 in.	
or,	3 rd.	2 yd.	1 ft.	13 in.	
or,	3 rd.	2 yd.	2 ft.	1 in.	Ans.

(113) We write the compound numbers so that the units of the same denomination shall stand in the same column. Beginning to add with the lowest denomination, we find that the sum of the gills is $1 + 2 + 3 = 6$. Since there are 4 gi. in 1 pint, in 6 gi. there are as many pints as 4 is contained times in 6, or 1 pt. and 2 gi. We place 2 gi. under the gills column and reserve the 1 pt. for the pints column; the sum of the pints is 1 (reserved) $+ 5 + 1 + 1 = 8$. Since there are 2 pt. in 1 quart, in 8 pt. there are as many quarts as 2 is contained times in 8, or 4 qt. and 0 pt. We place the cipher under the column of pints and reserve the 4 for the quarts column. The sum of the quarts is 4 (reserved) $+ 8 + 3 = 15$. Since there are 4 qt. in 1 gallon, in 15 qt. there are as many gallons as 4 is contained times in 15, or 3 gal. and 3 qt. remaining. We now place the 3 under the quarts column and reserve the 3 gal. for the gallons column. The sum of the gallons column is 3 (reserved) $+ 4 + 6 + 3 = 16$ gal. Since we can not reduce 16 gal. to any higher denomination, we have 16 gal. 3 qt. 0 pt. and 2 gi. for the answer.

gal.	qt.	pt.	gi.
3	3	1	3
6	0	1	2
4	0	0	1
	8	5	0
16 gal.	3 qt.	0 pt.	2 gi.

(114) Reduce the grains, pennyweights, and ounces to higher denominations.

$$24\,\underline{)\ 240\text{ gr.}} \qquad 20\,\underline{)\ 125\text{ pwt.}} \qquad 12\,\underline{)\ 50\text{ oz.}}$$
$$10\text{ pwt.} \qquad 6\text{ oz. }5\text{ pwt.} \qquad 4\text{ lb. }2\text{ oz.}$$

Then, 3 lb. + 4 lb. 2 oz. + 6 oz. 5 pwt. + 10 pwt. =

lb.	oz.	pwt.	
3			
4	2		
	6	5	
		10	
7 lb.	8 oz.	15 pwt.	Ans.

(115) Since "seconds" is the lowest denomination in this problem, we find their sum first, which is 11 + 29 + 25 + 30 + 12, or 107 seconds. Since there are 60 seconds in 1 minute, in 107″ there are as many minutes as 60 is contained times in 107, or 1 minute and 47 seconds remaining. We place the 47 under the seconds column and reserve the 1 for the minutes column. The sum of the minutes is 1 (reserved) + 17 + 26 + 19 + 16, or 79. Since there are 60 minutes in 1 degree, in 79 minutes there are as many degrees as 60 is contained times in 79, or 1 degree and 19 minutes remaining. We place the 19 under the minutes column and reserve the 1 degree for the degrees column. The sum of the degrees is 1 (reserved) + 10 + 20 + 13 + 11, or 55 degrees. Since we can not reduce 55 degrees to any higher denominations, we have 55° 19′ 47″ for the answer.

deg.	min.	sec.
11	16	12
13	19	30
20	0	25
0	26	29
10	17	11
55°	19′	47″

(116) Since "inches" is the lowest denomination in this problem, we find their sum first, which is 11 + 8 + 6, or 25 inches. Since there are 12 inches in 1 foot, in 25 inches there are as many feet as 12 is contained times in 25, or 2 feet and 1 inch remaining. Place the 1 inch under the inches column, and reserve the 2 feet to add to the column

of feet. The sum of the feet is 2 feet (reserved) + 2 + 1 = 5 feet. Since there are 3 feet in 1 yard, in 5 feet there are as many yards as 3 is contained times in 5 feet, or 1 yard and 2 feet remaining. Place the 2 feet under the column of feet, and reserve the 1 yard to add to the column of yards. The sum of the yards is 1 yard (reserved) + 4 + 5 = 10 yards. Since there are $5\frac{1}{2}$ yards in 1 rod, in 10 yards there are as many rods as $5\frac{1}{2}$ is contained times in 10, or 1 rod and $4\frac{1}{2}$ yards remaining. Place the $4\frac{1}{2}$ yards under the column of yards, and reserve the 1 rod for the column of rods. The sum of the rods is 1 (reserved) + 304 + 215 + 130 = 650 rods. Place 650 rods under the column of rods. Therefore, the sum is 650 rd. $4\frac{1}{2}$ yd. 2 ft. 1 in. Or, since $\frac{1}{2}$ a yard = 1 ft. 6 in., and since there are 320 rods in 1 mile, the sum may be expressed as 2 mi. 10 rd. 5 yd. 0 ft. 7 in. Ans.

	mi.	rd.	yd.	ft.	in.	
		130	5	1	6	
		215	0	2	8	
		304	4	0	11	
		650	$4\frac{1}{2}$	2	1	
or,	2	10	5	0	7	Ans.

(117) Since "square links" is the lowest denomination in this problem, we find their sum first, which is 21 + 23 + 16 + 18 + 23 + 21, or 122 square links. Place 122 square links under the column of square links. The sum of the square rods is 2 + 3 + 2 + 2 + 2 + 3, or 14 square rods. Place 14 square rods under the column of square rods. The sum of the square chains is 323 square chains. Since there are 10 square chains in 1 acre, in 323 square chains there are as many acres as 10 is

A.	sq. ch.	sq. rd.	sq. li.
21	67	3	21
28	78	2	23
47	6	2	18
56	59	2	16
25	38	3	23
46	75	2	21
255	3	14	122

contained times in 323 square chains, or 32 acres and 3 square chains remaining. Place 3 square chains under the column of square chains, and reserve the 32 acres to add to the column of acres. The sum of the acres is 32 acres (reserved) + 46 + 25 + 56 + 47 + 28 + 21, or 255 acres. Place 255 acres under the column of acres. Therefore, the sum is 255 A. 3 sq. ch. 14 sq. rd. 122 sq. li. Ans.

(118) Before we can subtract 300 ft. from 20 rd. 2 yd. 2 ft. and 9 in., we must reduce the 300 ft. to higher denominations.

Since there are 3 feet in 1 yard, in 300 feet there are as many yards as 3 is contained times in 300, or 100 yards. There are $5\frac{1}{2}$ yards in 1 rod, hence in 100 yards there are as many rods as $5\frac{1}{2}$ or $\frac{11}{2}$ is contained times in $100 = 18\frac{2}{11}$ rods.

$$100 \div \frac{11}{2} = 100 \times \frac{2}{11} = \frac{100 \times 2}{11} = \frac{200}{11}$$

$$\begin{array}{r} 11\,)\,200\,(\,18\frac{2}{11} \text{ rd.} \\ \underline{11}\phantom{\,(\,18\frac{2}{11} \text{ rd.}} \\ 90\phantom{\,(\,18\frac{2}{11} \text{ rd.}} \\ \underline{88}\phantom{\,(\,18\frac{2}{11} \text{ rd.}} \\ 2\phantom{\,(\,18\frac{2}{11} \text{ rd.}} \end{array}$$

Since there are $5\frac{1}{2}$ or $\frac{11}{2}$ yards in 1 rod, in $\frac{2}{11}$ rods there are $\frac{\cancel{2}}{\cancel{11}} \times \frac{\cancel{11}}{\cancel{2}}$, or one yard, so we find that 300 feet equals 18 rods and 1 yard. The problem now is as follows: From 20 rd. 2 yd. 2 ft. and 9 in. take 18 rd. and 1 yd.

We place the smaller number under the larger one, so that units of the same denomination fall in the same column. Beginning with the lowest denomination, we see that 0 inches from 9 inches leaves 9 inches. Going to the next higher denomination, we see that 0 feet from 2 feet leaves 2 feet. Subtracting 1 yard from 2

rd.	yd.	ft.	in.
20	2	2	9
18	1	0	0
2	1	2	9

yards, we have 1 yard remaining, and 18 rods from 20 rods leaves 2 rods. Therefore, the difference is 2 rd. 1 yd. 2 ft. 9 in. Ans.

(119)

A.	sq. rd.	sq. yd.	
114	80	25	
75	70	30	
39	9	$25\frac{1}{4}$	Ans.

EXPLANATION.—Place the subtrahend under the minuend so that like denominations are under each other. Then begin at the right with the lowest denomination. We can not subtract 30 from 25, so we take one square rod ($= 30\frac{1}{4}$ square yards) from 80 square rods, leaving 79 square rods; adding $30\frac{1}{4}$ square yards to 25 square yards, we have $55\frac{1}{4}$ square yards; subtracting 30 from $55\frac{1}{4}$ square yards leaves $25\frac{1}{4}$ square yards; we now subtract 70 square rods from 79 square rods, which leaves 9 square rods; next, we subtract 75 acres from 114 acres, which leaves 39 acres, which we place under the column of acres.

(120) If 10 gal. 2 qt. and 1 pt. of molasses are sold from a hogshead at one time, and 26 gal. 3 qt. are sold at another time, then the total amount of molasses sold equals 10 gal. 2 qt. 1 pt. plus 26 gal. 3 qt.

Since the pint is the lowest denomination, we add the pints first, which equal $0 + 1$, or 1 pint. We can not reduce 1 pint to any higher denomination, so we place it under the pint column. The number of quarts is $3 + 2$, or 5. Since there are 4 quarts in 1 gallon, in 5 quarts there are as many gallons as 4 is contained times in 5, or 1 gallon and 1 quart remaining. We place the 1 quart under the quart column, and reserve the 1 gallon to add to the column of

gal.	qt.	pt.
10	2	1
26	3	0
37 gal.	1 qt.	1 pt.

gallons. The number of gallons equals 1 (reserved) + 26 + 10, or 37 gallons.

If 37 gal. 1 qt. and 1 pt. are sold from a hogshead of molasses (63 gal.), there remains the difference between 63 gal. and 37 gal. 1 qt. 1 pt., or 25 gal. 2 qt. and 1 pt.

63 gal. is the same as 62 gal. 3 qt. 2 pt., since 1 gal. equals 4 qt. and 1 qt. = 2 pt.

Beginning with the lowest denomination, 1 pt. from the 2 pt. 1 pint from 2 pints leaves 1 pint. One quart from 3 quarts leaves 2 quarts, and 37 gallons from 62 gallons leaves 25 gallons. Therefore, there are 25 gal. 2 qt. and 1 pt. of molasses remaining in the hogshead. Ans.

gal.	qt.	pt.
62	3	2
37	1	1
25	2	1

(121) If a person were born June 19, 1850, in order to find how old he would be on Aug. 3, 1892, subtract the earlier date from the later date.

On August 3, 7 mo. and 3 da. have elapsed from the beginning of the year, and on June 19, 5 mo. and 19 da.

Beginning with the lowest denomination, we find that 19 days can not be taken from 3 days, so we take 1 month from 7 months. The 1 month which we took equals 30 days, for in all cases 30 days are allowed to a month. Adding 30 days to the 3 days, we have 33 days; subtracting 19 days from 33 days, we have 14 days remaining. Since we borrowed 1 month from the months column, we have 7 — 1, or 6 months remaining; subtracting 5 months from 6 months, we have 1 month remaining. 1850 from 1892 leaves 42 years. Therefore, he would be 42 years 1 month and 14 days old. Ans.

yr.	mo.	da.
1892	7	3
1850	5	19
42	1	14

(122) If a note given Aug. 5, 1890, were paid June 3, 1892, in order to find the length of time it was due, subtract the earlier date from the later date.

Beginning with the lowest denomination, we find that 5 can not be subtracted from 3, so we take a unit from the next

yr.	mo.	da.
1892	5	3
1890	7	5
1	9	28

higher denomination, which is months. The 1 month which we take equals 30 days. Adding the 30 days to the 3 days, we have 33 days. 5 days from 33 days leaves 28 days. Since we took 1 month from the months column, only 4 months remain. 7 months cannot be taken from 4 months, so we take 1 year from the years column, which equals 12 months. 12 months + 4 months = 16 months. 7 months from 16 months = 9 months. Since we took 1 year from the years column, we have 1892 − 1, or 1891 remaining. 1890 from 1891 leaves 1 year. Hence, the note ran 1 year 9 months and 28 days. Ans.

(123) Write the number of the year, month, day, hour, and minute of the earlier date under the year, month, day, hour, and minute of the later date, and subtract.

22 minutes before 8 o'clock is the same as 38 minutes after 7 o'clock. 7 o'clock P. M. is 19 hours from the beginning of the day, as there are 12 hours in the morning and 7 in the afternoon. December is 11 months from the beginning of the year.

10 o'clock A. M. is 10 hours from the beginning of the day. July is 6 months from the beginning of the year. The minuend would be the later date, or 1,888 years, 11 months, 11 days, 19 hours, and 38 minutes.

The subtrahend would be the earlier date, or 1,883 years, 6 months, 3 days, 10 hours, and 16 minutes.

Subtracting, we have

yr.	mo.	da.	hr.	min.
1888	11	11	19	38
1883	6	3	10	16
5	5	8	9	22

or, 5 yr. 5 mo. 8 da. 9 hr. and 22 min. Ans.

16 minutes subtracted from 38 minutes leaves 22 minutes; 10 hours from 19 hours leaves 9 hours; 3 days from 11 days leaves 8 days; 6 months subtracted from 11 months leaves 5 months; 1,883 from 1,888 leaves 5 years.

(124) In multiplication of denominate numbers, we place the multiplier under the lowest denomination of the multiplicand, as

17 ft.	3 in.
	51
879 ft.	9 in.

and begin at the right to multiply. $51 \times 3 = 153$ in. As there are 12 inches in 1 foot, in 153 in. there are as many feet as 12 is contained times in 153, or 12 feet and 9 inches remaining. Place the 9 inches under the inches, and reserve the 12 feet. 51×17 ft. $= 867$ ft. 867 ft. $+ 12$ ft. (reserved) $= 879$ ft.

879 feet can be reduced to higher denominations by dividing by 3 feet to find the number of yards, and by $5\frac{1}{2}$ yards to find the number of rods.

3) 8 7 9 ft. 9 in.
5.5) 2 9 3 yd.
5 3 rd. $1\frac{1}{2}$ yd.

Then, answer $= 53$ rd. $1\frac{1}{2}$ yd. 0 ft. 9 in.; or 53 rd. 1 yd. 2 ft. 3 in.

(125)

	qt.	pt.	gi.	
	3	1	3	
			4.7	
	1 8.2 qt.	0	.1	
or,	1 8 qt.	0 pt.	1.7 gi.	
or, 4 gal.	2 qt.	0 pt.	1.7 gi.	Ans.

Place the multiplier under the lowest denomination of the multiplicand, and proceed to multiply. 4.7×3 gi. $= 14.1$ gi. As 4 gi. $= 1$ pt., there are as many pints in 14.1 gi. as 4 is contained times in $14.1 = 3.5$ pt. and .1 gi. over. Place .1 under gills and carry the 3.5 pt. forward. 4.7×1 pt. $= 4.7$ pt.; $4.7 + 3.5$ pt. $= 8.2$ pt. As 2 pt. $= 1$ qt., there are as many quarts in 8.2 pt. as 2 is contained times in $8.2 = 4.1$ qt. and no pints over. Place a cipher under the pints, and carry the 4.1 qt. to the next product. 4.7×3 qt. $= 14.1$; $14.1 + 4.1 = 18.2$ qt. The answer now is 18.2 qt. 0 pt. .1

gi. Reducing the fractional part of a quart, we have 18 qt. 0 pt. 1.7 gi. (.2 qt. $= .2 \times 8 = 1.6$ gi.; $1.6 + .1$ gi. $= 1.7$ gi.). Then, we can reduce 18 qt. to gallons ($18 \div 4 = 4$ gal. and 2 qt.) = 4 gal. 2 qt. 1.7 gi. Ans.

The answer may be obtained in another and much easier way by reducing all to gills, multiplying by 4.7, and then changing back to quarts and pints. Thus,

$$\begin{array}{rl} & 3 \text{ qt.} \\ \times & 2 \\ \hline & 6 \text{ pt.} \\ + & 1 \text{ pt.} \\ \hline & 7 \text{ pt.} \\ \times & 4 \\ \hline & 28 \text{ gi.} \\ + & 3 \text{ gi.} \\ \hline & 31 \text{ gi.} \end{array}$$

3 qt. 1 pt. 3 gi. = 31 gi.
31 gi. $\times$ 4.7 = 145.7 gi.

$$\begin{array}{r} 4\,\underline{)\,145.7} \text{ gi.} \\ 2\,\underline{)\,36}\ \ \text{pt.} + 1.7 \text{ gi.} \\ 18\ \ \text{qt.} + \ \ 0 \text{ pt.} \end{array}$$

Ans. = 18 qt. 1.7 gi.;
or, 4 gal. 2 qt. 1.7 gi.

(126) (3 lb. 10 oz. 13 pwt. 12 gr.) $\times$ 1.5 = ?

$$\begin{array}{rl} & 3 \text{ lb. } 10 \text{ oz. } 13 \text{ pwt. } 12 \text{ gr.} \\ \times & 12 \\ \hline & 36 \text{ oz.} \\ + & 10 \\ \hline & 46 \text{ oz.} \\ \times & 20 \\ \hline & 920 \text{ pwt.} \\ + & 13 \\ \hline & 933 \text{ pwt.} \\ \times & 24 \\ \hline & 22392 \text{ gr.} \\ + & 12 \\ \hline & 22404 \text{ gr.} \end{array}$$

22,404 gr. $\times$ 1.5 = 33,606 gr.

$$\begin{array}{r} 24\,\underline{)\,33606} \text{ gr.} \\ 20\,\underline{)\,1400} \text{ pwt.} + 6 \text{ gr.} \\ 12\,\underline{)\,70} \text{ oz.} + 0 \text{ pwt.} \\ 5 \text{ lb.} + 10 \text{ oz.} \end{array}$$

Since there are 24 gr. in 1 pwt., in 33,606 gr. there are as many pwt. as 24 is contained times in 33,606, or 1,400 pwt. and 6 gr. remaining. This gives us the number of grains in the answer. We now reduce 1,400 pwt. to higher denominations. Since there are 20 pwt. in 1 oz., in 1,400 pwt. there are as many ounces as 20 is contained times in 1,400, or 70 oz. and 0 pwt. remaining; therefore, there are 0 pwt. in the answer. We reduce 70 oz. to higher denominations. Since there are 12 oz. in 1 lb., in 70 oz. there are as many pounds as 12 is contained times in 70, or 5 lb. and 10 oz. remaining. We can not reduce 5 lb. to any higher denominations. Therefore, our answer is 5 lb. 10 oz. 6 gr.

Another, but more complicated, way of working this problem is as follows:

	lb.	oz.	pwt.	gr.	
	3	10	13	12	
				1.5	
	4.5	15	19.5	18	
or,	4	21	19	30	
or,	5	10	0	6	Ans.

To get rid of the decimal in the pounds, reduce .5 of a pound to ounces. Since 1 lb. = 12 oz., .5 of a pound equals .5 lb. $\times$ 12 = 6 oz. 6 oz. + 15 oz. = 21 oz. We now have 4 lb. 21 oz. 19.5 pwt. and 18 gr., but we still have a decimal in the column of pwt., so we reduce .5 pwt. to grains to get rid of it. Since 1 pwt. = 24 gr., .5 pwt. = .5 pwt. $\times$ 24 = 12 gr. 12 gr. + 18 gr. = 30 gr. We now have 4 lb. 21 oz. 19 pwt. and 30 gr. Since there are 24 gr. in 1 pwt., in 30 gr. there is 1 pwt. and 6 gr. remaining. Place 6 gr. under the column of grains and add 1 pwt. to the pwt. column. Adding 1 pwt., we have 19 + 1 = 20 pwt. Since there are 20 pwt. in 1 oz., we have 1 oz. and 0 pwt. remaining. Write the 0 pwt. under the pwt. column, and reserve the 1 oz. to the oz. column. 21 oz. + 1 oz. = 22 oz. Since there are 12 oz. in 1 lb., in 22 oz. there is 1 lb. and 10 oz. remaining. Write the 10 oz. under the ounce column, and reserve the 1 lb. to add to the lb. column. 4 lb. + 1 lb. (reserved) = 5 lb. Hence, the answer equals 5 lb. 10 oz. 6 gr.

(127) If each barrel of apples contains 2 bu. 3 pk. and 6 qt., then 9 bbl. will contain 9 × (2 bu. 3 pk. 6 qt.).

We write the multiplier under the lowest denomination of the multiplicand, which is quarts in this problem. 9 times 6 qt. equals 54 qt. There are 8 qt. in 1 pk., and in 54 qt. there are as many pecks as 8 is contained times in 54, or 6 pk. and 6 qt. We write the 6 qt. under the column of quarts, and reserve the 6 pk. to add to the product of the pecks. 9 times 3 pk. equals 27 pk.; 27 pk. plus the 6 pk. reserved equals 33 pk. Since there are 4 pk. in 1 bu., in 33 pk. there are as many bushels as 4 is contained times in 33, or 8 bu. and 1 pk. remaining. We write the 1 pk. under the column of pecks, and reserve the 8 bu. for the product of the bushels. 9 times 2 bu. plus the 8 bu. reserved equals 26 bu. Therefore, we find that 9 bbl. contain 26 bu. 1 pk. 6 qt. of apples. Ans.

	bu.	pk.	qt.
	2	3	6
			9
	18	27	54
or,	26	1	6

(128) (7 T. 15 cwt. 10.5 lb.) × 1.7 = ? When the multiplier is a decimal, instead of multiplying the denominate numbers as in the case when the multiplier is a whole number, it is much easier to reduce the denominate numbers to the lowest denomination given; then, multiply that result by the decimal, and, lastly, reduce the product to higher denominations. Although the correct answer can be obtained by working examples involving decimals in the manner as in the last example, it is much more complicated than this method.

$$
\begin{array}{rl}
 & 7\text{ T. } 15\text{ cwt. } 10.5\text{ lb.} \\
\times & \underline{20} \\
 & 140\ \text{cwt.} \\
 & \underline{15} \\
 & 155\ \text{cwt.} \\
\times & \underline{100} \\
 & 15500\ \text{lb.} \\
 & \underline{10.5} \\
 & 15510.5\ \text{lb.}
\end{array}
$$

15,510.5 lb. × 1.7 = 26,367.85 lb.

There are 100 lb. in 1 cwt., and in 26,367.85 lb. there are as many cwt. as 100 is contained times in 26,367.85, which equals 263 cwt. and 67.85 lb. remaining. Since we have the number of pounds for our answer, we reduce 263 cwt. to higher denominations.

$$\begin{array}{r|l} 100 & \underline{2\,6\,3\,6\,7.8\,5 \text{ lb.}} \\ 20 & \underline{2\,6\,3 \text{ cwt.}} + 67.85 \text{ lb.} \\ & 1\,3 \text{ T.} + 3 \text{ cwt.} \end{array}$$

There are 20 cwt. in 1 ton, and in 263 cwt. there are as many tons as 20 is contained times in 263, or 13 tons and 3 cwt. remaining. Since we cannot reduce 13 tons any higher, our answer is 13 T. 3 cwt. 67.85 lb. Or, since .85 lb. = .85 lb. × 16 = 13.6 oz., the answer may be written 13 T. 3 cwt. 67 lb. 13.6 oz.

(129) 7) 358 A. 57 sq. rd. 6 sq. yd. 2 sq. ft.
51 A. 31 sq. rd. 0 sq. yd. 8 sq. ft. Ans.

We begin with the highest denomination, and divide each term in succession by 7.

7 is contained in 358 A. 51 times and 1 A. remaining. We write the 51 A. under the 358 A. and reduce the remaining 1 A. to square rods = 160 sq. rd.; 160 sq. rd. + the 57 sq. rd. in the dividend = 217 sq. rd. 7 is contained in 217 sq. rd. 31 times and 0 sq. rd. remaining. 7 is not contained in 6 sq. yd., so we write 0 under the sq. yd. and reduce 6 sq. yd. to square feet. 9 sq. ft. × 6 = 54 sq. ft. 54 sq. ft. + 2 sq. ft. in the dividend = 56 sq. ft. 7 is contained in 56 sq. ft. 8 times. We write 8 under the 2 sq. ft. in the dividend.

(130) 12) 282 bu. 3 pk. 1 qt. 1 pt.
23 bu. 2 pk. 2 qt. $\frac{1}{4}$ pt. Ans.

12 is contained in 282 bu. 23 times and 6 bu. remaining. We write 23 bu. under the 282 bu. in the dividend, and reduce the remaining 6 bu. to pecks = 24 pk. + the 3 pk. in the dividend = 27 pk. 12 is contained in 27 pk. 2 times and 3 pk. remaining. We write 2 pk. under the 3 pk. in the dividend, and reduce the remaining 3 pk. to quarts. 3 pk. = 24 qt.; 24 qt. + the 1 qt. in the dividend = 25 qt. 12 is contained in 25 qt. 2 times and 1 qt. remaining. We write

2 qt. under the 1 qt. in the dividend, and reduce 1 qt. to pints = 2 pt. + the 1 pt. in the dividend = 3 pt. $3 \div 12 = \frac{3}{12}$ or $\frac{1}{4}$ pt.

(131) We must first reduce 23 miles to feet before we can divide by 30 feet. 1 mi. contains 5,280 ft.; hence, 23 mi. contain $5,280 \times 23 = 121,440$ ft.

121,440 ft. $\div$ 30 ft. = 4,048 rails for 1 side of the track.

The number of rails for 2 sides of the track = $2 \times 4,048$, or 8,096 rails. Ans.

(132) In this case where both dividend and divisor are compound, reduce each to the lowest denomination mentioned in either and then divide as in simple numbers.

$$\begin{array}{r l}
1 \text{ bu. } 1 \text{ pk. } 7 \text{ qt.} & \\
\times 4 & \\
\hline
4 \text{ pk.} & \\
+1 & \\
\hline
5 \text{ pk.} & \\
\times 8 & \\
\hline
40 \text{ qt.} & \\
+7 & \\
\hline
47 \text{ qt.} &
\end{array}
\qquad
\begin{array}{r l}
356 \text{ bu. } 3 \text{ pk. } 5 \text{ qt.} & \\
\times 4 & \\
\hline
1424 \text{ pk.} & \\
+3 & \\
\hline
1427 \text{ pk.} & \\
\times 8 & \\
\hline
11416 \text{ qt.} & \\
+5 & \\
\hline
11421 \text{ qt.} &
\end{array}$$

$$\begin{array}{r}
47\,)\,11421\,(\,243 \\
94 \\
\hline
202 \\
188 \\
\hline
141 \\
141 \\
\hline
\end{array}$$

11,421 qt. $\div$ 47 qt. = 243 boxes. Ans.

(133) We must first reduce 16 square miles to acres.

In 1 sq. mi. there are 640 A., and in 16 sq. mi. there are 16×640 A. = 10,240 A.

$$\begin{array}{l}
62\,)\,10240 \text{ A.} \\
\hline
\quad 165 \text{ A. } 25 \text{ sq. rd. } 24 \text{ sq. yd. } 3 \text{ sq. ft. } 80+ \text{ sq. in.} \quad \text{Ans.}
\end{array}$$

62 is contained in 10,240 A. 165 times and 10 A. remaining. We write 165 A. under the 10,240 A. in the dividend and reduce 10 A. to sq. rd. In 1 A. there are 160 sq. rd., and in 10 A. there are $10 \times 160 = 1,600$ sq. rd. 62 is contained in 1,600 sq. rd. 25 times and 50 sq. rd. remaining. We write 25 sq. rd. in the quotient and reduce 50 sq. rd. to sq. yd. In 1 sq. rd. there are $30\frac{1}{4}$ sq. yd., and in 50 sq. rd. there are 50 times $30\frac{1}{4}$ sq. yd. $= 1,512\frac{1}{2}$ sq. yd. 62 is contained in $1,512\frac{1}{2}$ sq. yd. 24 times and $24\frac{1}{2}$ sq. yd. remaining. In 1 sq. yd. there are 9 sq. ft., and in $24\frac{1}{2}$ sq. yd. there are $24\frac{1}{2} \times 9 = 220\frac{1}{2}$ sq. ft. 62 is contained in $220\frac{1}{2}$ sq. ft. 3 times and $34\frac{1}{2}$ sq. ft. remaining. We write 3 sq. ft. in the quotient and reduce $34\frac{1}{2}$ sq. ft. to sq. in. In 1 sq. ft. there are 144 sq. in., and in $34\frac{1}{2}$ sq. ft. there are $34\frac{1}{2} \times 144 = 4,968$ sq. in. 62 is contained in 4,968 sq. in. 80 times and 8 sq. in. remaining.

We write 80 sq. in. in the quotient.

It should be borne in mind that it is only for the purpose of illustrating the method that this problem is carried out to square inches. It is not customary to reduce any lower than square rods in calculating the area of a farm.

(134) To square a number, we must multiply the number by itself once, that is, use the number twice as a factor. Thus, the second power of 108 is $108 \times 108 = 11,664$. Ans.

$$\begin{array}{r} 108 \\ 108 \\ \hline 864 \\ 108 \\ \hline 11664 \end{array}$$

(135)

```
        181.25
        181.25
        ------
        906 25
       3625 0
      18125
     145000
     18125
    ----------
    32851.5625
        181.25
    ----------
    16425781 25
    6570312 50
   32851562 5
  2628125000
  328515625
  ------------
  5954345.703125
```

The third power of 181.25 equals the number obtained by using 181.25 as a factor three times. Thus, the third power of 181.25 is $181.25 \times 181.25 \times 181.25 = 5,954,345.703125$. Ans.

Since there are 2 decimal places in the multiplier, and 2 in the multiplicand, there are $2 + 2 = 4$ decimal places in the first product.

Since there are 4 decimal places in the multiplicand, and 2 in the multiplier, there are $4 + 2 = 6$ decimal places in the final product.

(136)

```
            27.61
            27.61
            -----
            2761
          16566
         19327
         5522
         --------
         762.3121
            27.61
         --------
         7623121
       45738726
      53361847
     15246242
     -----------
     21047.437081
            27.61
     -----------
     21047437081
    126284622486
   147332059567
   42094874162
   ---------------
   581119.73780641
```

The fourth power of 27.61 is the number obtained by using 27.61 as a factor four times. Thus, the fourth power of 27.61 is $27.61 \times 27.61 \times 27.61 \times 27.61 = 581,119.73780641$. Ans.

Since there are 2 decimal places in the multiplier and 2 in the multiplicand, there are $2 + 2 = 4$ decimal places in the first product.

Since there are 4 decimal places in the multiplicand and 2 in the multiplier, there are $4 + 2 = 6$ decimal places in the second product.

Since there are 6 decimal places in the multiplicand and 2 in the multiplier, there are $6 + 2 = 8$ decimal places in the final product.

(137) (*a*) $106^2 = 106 \times 106 = 11,236$. Ans.

$$\begin{array}{r} 106 \\ 106 \\ \hline 636 \\ 1060 \\ \hline 11236 \end{array}$$

(*b*) $\left(182\frac{1}{8}\right)^2 = 182\frac{1}{8} \times 182\frac{1}{8} = 33,169.515625$. Ans.

$$\frac{1}{8} = 8\overline{)1.000} \atop .125$$

$$\begin{array}{r} 182.125 \\ 182.125 \\ \hline 910625 \\ 364250 \\ 182125 \\ 364250 \\ 1457000 \\ 182125 \\ \hline 33169.515625 \end{array}$$

Since there are 3 decimal places in the multiplier and 3 in the multiplicand, there are $3 + 3 = 6$ decimal places in the product.

(*c*) $.005^2 = .005 \times .005 = .000025$. Ans.

$$\begin{array}{r} .005 \\ .005 \\ \hline .000025 \end{array} \text{ Ans.}$$

Since there are 3 decimal places in the multiplicand and 3 in the multiplier, there are $3 + 3 = 6$ decimal places in the product.

(*d*) $.0063^2 = .0063 \times .0063 = .00003969$. Ans.

$$\begin{array}{r} .0063 \\ .0063 \\ \hline 189 \\ 378 \\ \hline .00003969 \end{array} \text{ Ans.}$$

Since there are 4 decimal places in the multiplicand and 4 in the multiplier, there are $4 + 4 = 8$ decimal places in the product.

(*e*) $10.06^2 = 10.06 \times 10.06 = 101.2036$. Ans.

$$\begin{array}{r} 10.06 \\ 10.06 \\ \hline 6036 \\ 100600 \\ \hline 101.2036 \end{array}$$

Since there are 2 decimal places in the multiplicand and 2 in the multiplier, there are $2 + 2 = 4$ decimal places in the product.

(138) (*a*) $753^3 = 753 \times 753 \times 753 = 426{,}957{,}777$. Ans.

$$\begin{array}{r}
753 \\
\underline{753} \\
2259 \\
3765 \\
\underline{5271} \\
567009 \\
\underline{753} \\
1701027 \\
2835045 \\
\underline{3969063} \\
426957777
\end{array}$$

(*b*) $987.4^3 = 987.4 \times 987.4 \times 987.4 = 962{,}674{,}279.624$. Ans.

$$\begin{array}{r}
987.4 \\
\underline{987.4} \\
39496 \\
69118 \\
78992 \\
\underline{88866} \\
974958.76 \\
\underline{987.4} \\
389983504 \\
682471132 \\
779967008 \\
\underline{877462884} \\
962674279.624
\end{array}$$

Since there is 1 decimal place in the multiplicand and 1 in the multiplier, there are $1 + 1 = 2$ decimal places in the first product.

Since there are 2 decimal places in the multiplicand and one in the multiplier, there are $2 + 1 = 3$ decimal places in the final product.

(*c*) $.005^3 = .005 \times .005 \times .005 = .000000125$. Ans.

$$\begin{array}{r}
.005 \\
\underline{.005} \\
.000025 \\
\underline{.005} \\
.000000125
\end{array}$$

Since there are 3 decimal places in the multiplicand and 3 in the multiplier, there are $3 + 3 = 6$ decimal places in the first product; but, as there are only 2 figures in the product, we prefix four ciphers to make the six decimal places.

Since there are six decimal places in the multiplicand and 3 in the multiplier, there are $6 + 3 = 9$ decimal places in the final product. In this case we prefix six ciphers to form the nine decimal places.

(*d*) $.4044^3 = .4044 \times .4044 \times .4044 = .066135317184$. Ans.

$$\begin{array}{r}
.4044 \\
.4044 \\
\hline
16176 \\
16176 \\
161760 \\
\hline
.16353936 \\
.4044 \\
\hline
65415744 \\
65415744 \\
654157440 \\
\hline
.066135317184
\end{array}$$

Since there are 4 decimal places in the multiplicand and 4 in the multiplier, there are $4 + 4 = 8$ decimal places in the first product.

Since there are 8 decimal places in the second multiplicand and 4 in the multiplier, there are $8 + 4 = 12$ decimal places in the final product; but, as there are only 11 figures in the product, we prefix 1 cipher to make 12 decimal places.

(139) $2^5 = 2 \times 2 \times 2 \times 2 \times 2 = 32$. Ans.

(140) $3^4 = 3 \times 3 \times 3 \times 3 = 81$. Ans.

(141) (*a*) $67.85^2 = 67.85 \times 67.85 = 4{,}603.6225$. Ans.

$$\begin{array}{r}
67.85 \\
67.85 \\
\hline
33925 \\
54280 \\
47495 \\
40710 \\
\hline
4603.6225
\end{array}$$ Ans.

Since there are 2 decimal places in the multiplier and 2 in the multiplicand, there are $2 + 2 = 4$ decimal places in the product.

(*b*) $967{,}845^2 = 967{,}845 \times 967{,}845 = 936{,}723{,}944{,}025$. Ans.

$$\begin{array}{r}
967845 \\
967845 \\
\hline
4839225 \\
3871380 \\
7742760 \\
6774915 \\
5807070 \\
8710605 \\
\hline
936723944025
\end{array}$$

(*c*) A fraction may be raised to any power by raising both numerator and denominator to the required power.

Thus, $\left(\frac{3}{8}\right)^2 = \frac{3}{8} \times \frac{3}{8} = \frac{3 \times 3}{8 \times 8} = \frac{9}{64}$. Ans.

(*d*) $\left(\frac{1}{4}\right)^2 = \frac{1}{4} \times \frac{1}{4} = \frac{1 \times 1}{4 \times 4} = \frac{1}{16}$. Ans.

(142) (*a*) $5^{10} = 5 \times 5 \times 5 \times 5 \times 5 \times 5 \times 5 \times 5 \times 5 \times 5 =$ 9,765,625. Ans.

(*b*) $9^5 = 9 \times 9 \times 9 \times 9 \times 9 = 59{,}049$. Ans.

$$
\begin{array}{r}
5 \\
5 \\
\hline
25 \\
5 \\
\hline
125 \\
5 \\
\hline
625 \\
5 \\
\hline
3125 \\
5 \\
\hline
15625 \\
5 \\
\hline
78125 \\
5 \\
\hline
390625 \\
5 \\
\hline
1953125 \\
5 \\
\hline
9765625
\end{array}
\qquad\qquad
\begin{array}{r}
9 \\
9 \\
\hline
81 \\
9 \\
\hline
729 \\
9 \\
\hline
6561 \\
9 \\
\hline
59049
\end{array}
$$

(143) (*a*) $1.2^4 = 1.2 \times 1.2 \times 1.2 \times 1.2 = 2.0736$. Ans. Since there is 1 decimal place in the multiplicand and 1 in the multiplier, we must point off $1 + 1 = 2$ decimal places in the first product.

Since there are 2 decimal places in the second multiplicand and 1 in the multiplier, we must point off $2 + 1 = 3$ decimal places in the second product.

Since there are 3 decimal places in the third multiplicand and 1 in the multiplier, we must point off $3 + 1 = 4$ decimal places in the final product.

$$\begin{array}{r}
1.2 \\
1.2 \\
\hline
2\,4 \\
1\,2 \\
\hline
1.4\,4 \\
1.2 \\
\hline
2\,8\,8 \\
1\,4\,4 \\
\hline
1.7\,2\,8 \\
1.2 \\
\hline
3\,4\,5\,6 \\
1\,7\,2\,8 \\
\hline
2.0\,7\,3\,6
\end{array}$$

(*b*) $11^6 = 11 \times 11 \times 11 \times 11 \times 11 \times 11 = 1{,}771{,}561.$ Ans.

$$\begin{array}{r}
11 \\
11 \\
\hline
121 \\
11 \\
\hline
1331 \\
11 \\
\hline
14641 \\
11 \\
\hline
161051 \\
11 \\
\hline
1771561
\end{array}$$

(*c*) $1^7 = 1 \times 1 \times 1 \times 1 \times 1 \times 1 \times 1 = 1$. Ans.

(*d*) $.01^4 = .01 \times .01 \times .01 \times .01 = .00000001$. Ans.

Since there are 2 decimal places in the multiplicand and 2 in the multiplier, we must point off $2 + 2 = 4$ decimal places in the first product; but, as there is only 1 figure in the product, we prefix 3 ciphers to make the 4 necessary decimal places.

$$\begin{array}{r} .01 \\ .01 \\ \hline .0001 \\ .01 \\ \hline .000001 \\ .01 \\ \hline .00000001 \end{array}$$

Since there are 4 decimal places in the second multiplicand and 2 in the multiplier, we must point off $4 + 2 = 6$ decimal places in the second product. It is necessary to prefix 5 ciphers to make 6 decimal places.

Since there are 6 decimal places in the third multiplicand and 2 in the multiplier, we must point off $6 + 2 = 8$ decimal places in the product. It is necessary to prefix 7 ciphers to make 8 decimal places in the final product.

(*c*) $.1^5 = .1 \times .1 \times .1 \times .1 \times .1 = .00001$. Ans.

Since there is 1 decimal place in the multiplicand and 1 in the multiplier, we must point off $1 + 1 = 2$ decimal places in the first product. It is necessary to prefix 1 cipher to the product.

$$\begin{array}{r} .1 \\ .1 \\ \hline .01 \\ .1 \\ \hline .001 \\ .1 \\ \hline .0001 \\ .1 \\ \hline .00001 \end{array}$$

Since there are 2 decimal places in the second multiplicand and 1 in the multiplier, we must point off $2 + 1 = 3$ decimal places in the second product. It is necessary to prefix 2 ciphers to the second product.

Since there are 3 decimal places in the third multiplicand and 1 in the multiplier, we must point off $3 + 1 = 4$ decimal places in the third product. It is necessary to prefix 3 ciphers to this product.

Since there are 4 decimal places in the fourth multiplicand and 1 in the multiplier, we must point off $4 + 1$ or 5 decimal places in the final product. It is necessary to prefix 4 ciphers to this product.

(144) (*a*) $.0133^3 = .0133 \times .0133 \times .0133 = .000002352637$. Ans.

Since there are 4 decimal places in the multiplicand and 4 in the multiplier, we must point off $4 + 4 = 8$ decimal places in the product; but, as there are only 5 figures in the product, we prefix three ciphers to form the eight necessary decimal places in the first product.

Since there are 8 decimal places in the multiplicand and 4 in the multiplier, we must point off $8 + 4 = 12$ decimal places in the product; but, as there are only 7 figures in the product, we prefix 5 ciphers to make the 12 necessary decimal places in the final product.

```
         .0133
         .0133
         -----
           399
          399
         133
     ---------
     .00017689
         .0133
     ---------
         53067
        53067
       17689
 -------------
 .000002352637
```

(*b*) $301.011^3 = 301.011 \times 301.011 \times 301.011 =$ 27,273,890.942264331. Ans.

Since there are 3 decimal places in the multiplicand and 3 in the multiplier, we must point off $3 + 3 = 6$ decimal places in the first product.

Since there are 6 decimal places in the multiplicand and 3 in the multiplier, we must point off $6 + 3 = 9$ decimal places in the final product.

```
             301.011
             301.011
             -------
             301011
            301011
          3010110
         9030330
         ------------
         90607.622121
              301.011
         ------------
          90607622121
         90607622121
       906076221210
    27182286636630
    -----------------
    27273890.942264331
```

(*c*) $\left(\frac{1}{8}\right)^3 = \frac{1}{8} \times \frac{1}{8} \times \frac{1}{8} = \frac{1 \times 1 \times 1}{8 \times 8 \times 8} = \frac{1}{512}$. Ans.

(*d*) To find any power of a mixed number, first reduce it to an improper fraction, and then multiply the numerators together for the numerator of the answer, and multiply the denominators together for the denominator of the answer.

$$\left(3\frac{3}{4}\right)^3 = \frac{15}{4} \times \frac{15}{4} \times \frac{15}{4} = \frac{15 \times 15 \times 15}{4 \times 4 \times 4} = \frac{3,375}{64} = 52.734+. \text{ Ans.}$$

$$3\frac{3}{4} = \frac{3 \times 4 + 3}{4} = \frac{12 + 3}{4} = \frac{15}{4}.$$

$$\begin{array}{r}
15 \\
15 \\
\hline
75 \\
15 \\
\hline
225 \\
15 \\
\hline
1125 \\
225 \\
\hline
3375
\end{array}
\qquad\qquad
\begin{array}{l}
64)3375.000(52.734+ \\
320 \\
\overline{175} \\
128 \\
\overline{470} \\
448 \\
\overline{220} \\
192 \\
\overline{280} \\
256 \\
\overline{24}
\end{array}$$

Since *three* ciphers were annexed to the dividend, *three* decimal places must be pointed off in the quotient. It is easy to see that the next figure will be a 3; hence, write the sign +, as shown.

(**145**) Evolution is the reverse of involution. In involution we find the *power* of a number by multiplying the number by itself one or more times, while in evolution we find the *number* or *root* which was multiplied by itself one or more times to make the power.

(146) (*a*)

$$\begin{array}{r}
1 \\
\underline{1} \\
20 \\
\underline{8} \\
28 \\
\underline{8} \\
360 \\
\underline{6} \\
366 \\
\underline{6} \\
3720 \\
\underline{7} \\
3727 \\
\underline{7} \\
3734
\end{array}$$

$\sqrt{3'48'67'84.40'10} = 1867.29+$ **Ans.**

$$\begin{array}{l}
\underline{1} \\
248 \\
\underline{224} \\
\;\;2467 \\
\;\;\underline{2196} \\
\;\;\;\;27184 \\
\;\;\;\;\underline{26089}
\end{array}$$

$$\begin{array}{l}
3734)\,1095.000\,(.293 \text{ or } .29+ \\
\qquad\quad \underline{7468} \\
\qquad\quad 34820 \\
\qquad\quad \underline{33606} \\
\qquad\quad\;\; 12140
\end{array}$$

EXPLANATION.—Applying the short method described in Art. **272**, we extract the root by the regular method to four figures, since there are six figures in the answer, and $6 \div 2 + 1 = 4$. The last remainder is 1095, and the last trial divisor (with the cipher omitted) is 3734. Dividing 1095 by 3734, as shown, the quotient is $.293+$, or $.29+$ using two figures. Annexing to the root, gives $1,867.29+$. Ans.

(*b*) (*a*) 3 $\sqrt{9'00'00'99.40'09'00} = $ **3000.0165+Ans.**

	3	(*b*) 9
(*d*)	60 (*c*)	0000994009
	0	600001
	600	39400800
	0	36000156
	6000	3400644
	0	
	60000	
	0	
	600000	
	1	
	600001	
	1	
	6000020	
	6	
	6000026	

Explanation.—Beginning at the decimal point we point off the whole number into periods of *two* figures each, proceeding from *right* to *left*; also, point off the decimal into periods of *two* figures each, proceeding from *left* to *right*. The largest number whose square is contained in the first period, 9, is 3; hence, 3 is the first figure of the root. Place 3 at the left, as shown at (*a*), and multiply it by the first figure in the root, or 3. The result is 9. Write 9 under the first period, 9, as at (*b*), subtract, and there is no remainder. Bring down the next period, which is 00, as shown at (*c*). Add the root already found to the 3 at (*a*), obtaining 6, and annex a cipher to this 6, thus making it 60, which is the *trial divisor*, as shown at (*d*). Divide the dividend (*c*) by the trial divisor, and obtain 0 as the next figure in the root. Write 0 in the root, as shown, and also add it to the trial divisor, 60, and annex a cipher, thereby making the next trial divisor 600. Bring down the next period, 00, annex it to the dividend already obtained, and divide it by the trial divisor. 600 is contained in 0000, 0 times, so we place another cipher

in the root. Write 0 in the root, as shown, and also add it to the trial divisor, 600, and annex a cipher, thereby making the next trial divisor 6,000. Bring down the next period, 99. The trial divisor 6,000 is contained in 000099, 0 times, so we place 0 as the next figure in the root, as shown, and also add it to the trial divisor 6,000, and annex a cipher, thereby making the next trial divisor 60,000. Bring down the next period, 40, and annex it to the dividend already obtained to form the new dividend, 00009940, and divide it by the trial divisor 60,000. 60,000 is contained in 00009940, 0 times, so we place another cipher in the root, as shown, and also add it to the trial divisor 60,000, and annex one cipher, thereby making the next trial divisor 600,000. Bring down the next period, 09, and annex it to the dividend already obtained to form the new dividend, 0000994009, and divide it by the trial divisor 600,000. 600,000 is contained in 0000994009 once, so we place 1 as the next figure in the root, and also add it to the trial divisor 600,000, thereby making the complete divisor 600,001. Multiply the complete divisor, 600,001, by 1, the sixth figure in the root, and subtract the result obtained from the dividend. The remainder is 394,008, to which we annex the next period, 00, to form the next new dividend, or 39,400,800. Add the sixth figure of the root, or 1, to the divisor 600,001, and annex a cipher, thus obtaining 6,000,020 as the next trial divisor. Dividing 39,400,800 by 6,000,020, we find 6 to be the next figure of the root. Adding this last figure, 6, to the trial divisor, we obtain 6,000,026 for our next complete divisor, which, multiplied by the last figure of the root, or 6, gives 36,000,156, which write under 39,400,800 and subtract. Since there is a remainder, it is clearly evident that the given power is not a perfect square, so we place + after the root. Since the next figure is 5, the answer is 3,000.017 −.

In this problem there are *seven* periods—four in the whole number and three in the decimal—hence, there will be *seven* figures in the root, *four* figures constituting the whole number, and three figures the decimal of the root. Hence, $\sqrt{9{,}000{,}099.4009} = 3{,}000.017 -$

(*c*)

$$
\begin{array}{l}
3 \\
\underline{3} \\
60 \\
\underline{5} \\
65
\end{array}
\qquad
\begin{array}{l}
\sqrt{.00'12'25} = .035. \quad \text{Ans.} \\
\underline{00} \\
12 \\
\underline{9} \\
325 \\
\underline{325}
\end{array}
$$

Pointing off periods, we find that the first period is composed of ciphers; hence, the first figure of the root will be a cipher. No further explanation is necessary, since this problem is solved in a manner exactly similar to the problem solved in Art. **264.** Since there are *three* decimal periods in the power, there will be three decimal figures in the root.

(**147**) (*a*)

$$
\begin{array}{r}
1 \\
\underline{1} \\
20 \\
\underline{0} \\
200 \\
\underline{3} \\
203 \\
\underline{3} \\
2060 \\
\underline{9} \\
2069
\end{array}
\qquad
\begin{array}{l}
\sqrt{1'07'95.21} = 103.9 \quad \text{Ans.} \\
\underline{1} \\
0795 \\
\underline{609} \\
18621 \\
\underline{18621}
\end{array}
$$

(*b*)

$$
\begin{array}{r}
2 \\
\underline{2} \\
40 \\
\underline{7} \\
47 \\
\underline{7} \\
5400 \\
\underline{2} \\
5402
\end{array}
\qquad
\begin{array}{l}
\sqrt{7'30'08.04} = 270.2 \quad \text{Ans} \\
\underline{4} \\
330 \\
\underline{329} \\
10804 \\
\underline{10804}
\end{array}
$$

(*c*)

9	$\sqrt{90.00'00'00} = 9.487 -$ Ans.
9	81
180	900
4	736
184	16400
4	15104
1880	1896) 1296.00 (.68 + or .7 −
8	11376
1888	15840
8	15168
1896	

Having found the first three figures, we find the fourth by division, as shown.

(*d*) $\sqrt{.09} = .3.$ Ans.

(148) (*a*)

6	36	$\sqrt[3]{.327'680'000} = .6894 +$ Ans.
6	72	216
12	10800	111680
6	1504	98432
180	12304	13248000
8	1568	12650769
188	1387200	1424163) 597231.00(.41+or.4+
8	18441	5696652
196	1405641	2756580
8	18522	1424163
2040	1424163	
9		
2049		
9		
2058		

Here we find the first three figures in the regular way, and the fourth figure by the short method. See Art. **284.**

EXPLANATION.—(1) When extracting the *cube* root we divide the power into periods of three figures each. Always begin at the decimal point, and proceed to the *left* in pointing off the whole number, and to the *right* in pointing off the decimal. In this power .32768, a cipher must be annexed to 68 to complete the second decimal period. Cipher periods may now be annexed until the root has as many figures as desired.

(2) We find by trial that the largest number whose cube is contained in the first period, 327, is 6. Write 6 as the first figure of the root, also at the extreme left at the head of column (1). Multiply the 6 in column (1) by the first figure of the root, 6, and write the product 36 at the head of column (2). Multiply the number in column (2) by the first figure of the root, 6, and write the product 216 under the figures in the first period. Subtract and bring down the next period 680; annex it to the remainder 111, thereby obtaining 111,680 for a new dividend. Add the first figure of the root, 6, to the number in column (1), obtaining 12, which we call the *first correction;* multiply the first correction 12 by the first figure of the root, and we obtain 72 as the product, which, added to 36 of column (2), gives 108. Annexing two ciphers to 108, we have 10,800 for the trial divisor. Dividing the dividend by the trial divisor, we see that it is contained about 8 times, so we write 8 as the second figure of the root. Add the first figure of the root to the first correction, and we obtain 18 as the *second correction.* To this annex *one* cipher, and add the second figure of the root, and we obtain 188. This, multiplied by the second figure of the root, 8, equals 1,504, which, added to the trial divisor 10,800, forms the *complete divisor* 12,304. Multiplying the complete divisor 12,304 by 8, the second figure of the root, the result is 98,432. Write 98,432 under the dividend 111,680; subtract, and there is a remainder of 13,248. To this remainder annex the next period 000, thereby obtaining 13,248,000 for the next new dividend.

(3) Adding the second figure of the root, 8, to the number in column (1), 188, we have 196 for the *first new*

correction. This, multiplied by the second figure of the root, 8, gives 1,568. Adding this product to the last complete divisor, and annexing two ciphers, gives 1,387,200 for the next trial divisor. Adding the second figure of the root, 8, to the first new correction, 196, we obtain 204 for the *new second correction.* Dividing the dividend by the trial divisor 1,387,200, we see that it is contained about 9 times. Write 9 as the third figure of the root. Annex *one* cipher to the *new second correction,* and to this add the third figure of the root, 9, thereby obtaining 2,049. This, multiplied by 9, the third figure of the root, equals 18,441, which, added to the trial divisor, 1,387,200, forms the complete divisor 1,405,641. Multiplying the complete divisor by the third figure of the root, 9, and subtracting, we have a remainder of 597,231. We then find the fourth figure by division, as shown.

(*b*)

	4	16	$\sqrt[3]{74'088} = 42$ Ans.
	4	32	64
	8	4800	10088
	4	244	10088
	120	5044	
	2		
	122		

(*c*)

4	16	$\sqrt[3]{92'416} = 45.212 -$ Ans.
4	32	64
8	4800	28416
4	625	27125
120	5425	1291000
5	650	1220408
125		
5	607500	612912)70592.000(.115
130	2704	612912
5	610204	930080
1350	2708	612912
2		
1352	612912	3171680
2		3064560
1354		107120

(*d*)

7	49	$\sqrt[3]{.373'248} = .72$ Ans.
7	98	343
14	14700	30248
7	424	30248
210	15124	
2		
212		

(149)

1	1	$\sqrt[3]{2.000'000'000} = 1.259921 +$ Ans.
1	2	1
2	300	1000
1	64	728
30	364	272000
2	68	225125
32	43200	46875000
2	1825	42491979
34	45025	4755243) 4383021.000 (.9217 or .922−
2	1850	42797187
360	4687500	10330230
5	33831	9510486
365	4721331	8197440
5	33912	4755243
370	4755243	34421970
5		
3750		
9		
3759		
9		
3768		

This example shows what a great saving of figures is effected by using the short method. The figures obtained by the division are 9217, thus making the last figures of the answer 922, according to Art. **272.** This is not correct in this case; the true answer to eight decimal places being 1.25992104 +; hence, the first three figures

found by division should be used in this case. The reason for the apparent failure of the method in this case to give the seventh figure of the root correctly is because the fifth figure (the first obtained by division) is 9. Whenever the first figure obtained by division is 8 or 9, it is better to carry the root process one place further, before applying Art. **272,** if it is desired to obtain absolutely correct results.

(150) (*a*)

1	1	$\sqrt[3]{1'758.416'743} = 12.07$ Ans.
1	2	1
2	300	758
1	64	728
30	364	30416743
2	68	30416743
32	4320000	
2	25249	
34	4345249	
2		
3600		
7		
3607		

(*b*)

1	1	$\sqrt[3]{1'191'016} = 106$ Ans.
1	2	1
2	30000	191016
1	1836	191016
300	31836	
6		
306		

(*c*) $\sqrt[3]{\frac{4}{32}} = \sqrt[3]{\frac{1}{8}} = \frac{\sqrt[3]{1}}{\sqrt[3]{8}} = \frac{1}{2}$. Ans

(*d*) $\sqrt[3]{\frac{27}{512}} = \frac{\sqrt[3]{27}}{\sqrt[3]{512}} = \frac{3}{8}$. Ans.

(151)

1	1	$\sqrt[3]{3.000'000'000} = 1.442250 -$ Ans.
1	2	1
2	300	2000
1	136	1744
30	436	256000
4	152	241984
34	58800	14016000
4	1696	12458888
38	60496	6238092) 1557112.000 (.2496 or .250 −
4	1712	12476184
420	6220800	30949360
4	8644	24952368
424	6229444	59969920
4	8648	56142828
428	6238092	8827092
4		
4320		
2		
4322		
2		
4324		

(152) (*a*)

1	$\sqrt{1'23.21} = 11.1$ Ans.
1	1
20	23
1	21
21	221
1	221
220	
1	
221	

(*b*)

1	$\sqrt{1'14.92'10} = 10.72 +$ Ans.
1	1
200	1492
7	1449
207	4310
7	4284
2140	26
2	
2142	

(*c*)

7	$\sqrt{50'26'81} = 709$ Ans.
7	49
140	12681
0	12681
1400	
9	
1409	

(*d*)

2	$\sqrt{.00'04'12'09} = .0203$ Ans.
2	00
400	04
3	4
403	1209
	1209

(153) (*a*)

1	1	$\sqrt[3]{.006'500'000} = .18663 -$ Ans.
1	2	1
2	300	5500
1	304	4832
30	604	668000
8	368	602856
38	97200	103788) 65144.00 (.627 or .63 −
8	3276	622728
46	100476	287120
8	3312	207576
540	103788	79544
6		
546		
6		
552		

(*b*)

2	4	$\sqrt[3]{.021'000'000} = .2759 -$ Ans.
2	8	8
4	1200	13000
2	469	11683
60	1669	1317000
7	518	1113875
67	218700	226875) 203125.0 (.89 or .9−
7	4075	1815000
74	222775	216250
7	4100	
810	226875	
5		
815		
5		
820		

(*c*)

2	4	$\sqrt[3]{8'036'054'027} = 2{,}003$ Ans.
2	8	8
4	12000000	036054027
2	18009	36054027
6000	12018009	
3		
6003		

(*d*)

1	1	$\sqrt[3]{.000'004'096} = .016$ Ans.
1	2	000
2	300	004
1	216	1
30	516	3096
6		3096
36		

(*e*)

2	4	$\sqrt[3]{17.000'000} = 2.5713-$ Ans.
2	8	8
4	1200	9000
2	325	7625
60	1525	1375000
5	350	1349593
65	187500	198147) 25407.00 (.128 or .13 –
5	5299	198147
70	192799	559230
5	5348	396294
750	198147	162936
7		
757		
7		
764		

(154) (*a*) In this example the index is 4, and equals 2×2. The root indicated is the fourth root, hence the square root must be extracted twice. Thus, $\sqrt[4]{\ } = \sqrt{\ }$ of the $\sqrt{\ }$ and $\sqrt[4]{6561} = \sqrt{\sqrt{6561}} = \sqrt{81} = 9$. Ans.

8	$\sqrt{65'61} = 81$	$\sqrt{81} = 9$ Ans.
8	64	
160	161	
1	161	
161		

(*b*) In this example the index is 6, and 6 equals 3×2 or 2×3. The root indicated is the sixth root; hence, extract both the square and cube root, it making no particular difference as to which root is extracted first. Thus,

$$\sqrt[6]{\ } = \sqrt[3]{\ } \text{ of the } \sqrt{\ }, \text{ or } \sqrt{\ } \text{ of the } \sqrt[3]{\ }.$$

Hence, $\sqrt[6]{117,649} = \sqrt[3]{\sqrt{117,649}} = \sqrt[3]{343} = 7$. Ans.

3	$\sqrt{11'76'49} = 343$	$\sqrt[3]{343} = 7$ Ans.
3	9	
60	276	
4	256	
64	2049	
4	2049	
680		
3		
683		

(*c*) $\sqrt[6]{.000064} = \sqrt[3]{\sqrt{.000064}} = .2$. Ans.

$\sqrt{.000064} = .008$. $\sqrt[3]{.008} = .2$. Hence, $\sqrt[6]{.000064} = .2$. Ans.

(*d*) $\sqrt[3]{\frac{3}{8}} = ?$ $\frac{3}{8} = .375$, since $8\overline{)3.000}$
.375

7	49	$\sqrt[3]{.375'000'000} = .72112+$ Ans.
7	98	343
14	14700	32000
7	424	30248
210	15124	1752000
2	428	1557361
212	1555200	1559523) 19463 9.00 (.124 or .12 +
2	2161	1559523
214	1557361	3868670
2	2162	3119046
2160	1559523	749624
1		
2161		
1		
2162		

Hence, $\sqrt[3]{\frac{3}{8}} = .72112+$. Ans.

(155) (*a*) $\sqrt{\frac{1225}{5476}} = \frac{\sqrt{1225}}{\sqrt{5476}}$.

3	$\sqrt{12'25} = 35$
3	9
60	325
5	325
65	

Hence, $\sqrt{\frac{1225}{5476}} = \frac{35}{74}$. Ans.

7	$\sqrt{54'76} = 74$
7	49
140	576
4	576
144	

(*b*)

5	$\sqrt{.33'64} = .58$ Ans.
5	25
100	864
8	864
108	

(*c*)

3	$\sqrt{.10'00'00'00} = .31623-$ Ans.
3	9
60	100
1	61
61	3900
1	3756
620	632) 144.00 (.227 or .23 −
6	1264
626	1760
6	1264
632	496

(*d*) $25.0\frac{3}{4} = 25.075.$

5	$\sqrt{25.07'50'00'00'00} = 5.00749+$ Ans.
5	25
10000	075000
7	70049
10007	495100
7	400576
100140	9452400
4	9013401
100144	438999
4	
1001480	
9	
1001489	

(*e*) $.000\frac{4}{9} = .0004444444+.$

2	$\sqrt{.00'04'44'44'44} = .02108+$ Ans.
2	00
40	04
1	4
41	44
1	41
4200	34444
8	33664
4208	780

(156) (*a*) $\sqrt[4]{2} = \sqrt{\sqrt{2}}$.

1	$\sqrt{2.00'0000'00} = 1.41421356+$
1	1
20	100
4	96
24	400
4	281
280	11900
1	11296
281	60400
1	56564
2820	28284) 3836.0000 (.13562 or .1356+
4	28284
2824	100760
4	84852
28280	159080
2	141420
28282	176600
2	169704
28284	6896

1	$\sqrt{1.41'42'13'56} = 1.1892+$ Ans.
1	1
20	41
1	21
21	2042
1	1824
220	21813
8	21321
228	49256
8	47564
2360	1692
9	
2369	
9	
23780	
2	
23782	

It is required in this problem to extract the fourth root of 2 to four decimal places; hence, we must extract the square root twice, since $\sqrt[4]{\ } = \sqrt{\ }$ of the $\sqrt{\ }$. In the first operation we carry the root to 8 decimal places, in order to carry the root in the second operation to 4 decimal places.

(*b*) $\sqrt[6]{6} = \sqrt[3]{\sqrt{6}}.$

2	$\sqrt{6.00'00'00'00'00'00} = 2.4494897428+$
2	4
40	200
4	176
44	2400
4	1936
480	46400
4	44001
484	239900
4	195936
4880	4396400
9	3919104
4889	489896)477296.00000(.974280 or 97428 +
9	4409064
48980	3638960
4	3429272
48984	2096880
4	1959584
489880	1372960
8	979792
489888	3931680
8	3919168
489896	12512

It is required in this problem to find the sixth root of 6; hence it is necessary to extract both the square and cube roots in succession, since the index, 6, equals 2×3 or 3×2. It makes no particular difference as to which root we extract first, but it will be more convenient to extract the square root first. The result has been carried to 10 decimal places; since the answer requires but 5 decimal places, the remaining decimals will not affect the cube root in the fifth decimal place, as the student can see for himself if he will continue the operation.

1	1	$\sqrt[3]{2.449'489'742'800} = 1.34801-$ Ans.
1	2	1
2	300	1449
1	99	1197
30	399	252489
3	108	209104
33	50700	43385742
3	1576	43352192
36	52276	5451312) 33550.000 (.006 or .01 −
3	1592	32707872
390	5386800	842128
4	32224	
394	5419024	
4	32288	
398	5451312	
4		
4020		
8		
4028		
8		
4036		

(157) (*a*)

1	$\sqrt{3.14'16} = 1.7725-$ Ans.
1	1
20	214
7	189
27	2516
7	2429
340	354) 87.00 (.245 + or .25 −
7	708
347	1620
7	1416
354	204

(b)

8
8
160
8
168
8
1760
6
1766
6
1772

$\sqrt{.78'54'00} = .8862 +$ Ans.

64
1454
1344
11000
10596
1772) 404.0 (.22 or .2+
3544
496

(158) (a)

1
1
2
1
30
4
34
4
38
4
420
6
426
6
432
6
4380
4
4384
4
4388

1
2
300
136
436
152
58800
2556
61356
2592
6394800
17536
6412336
17552
6429888

$\sqrt[3]{3.141'600'000} = 1.4646 -$ Ans

1
2141
1744
397600
368136
29464000
25649344
6429888) 3814656.0 (.59 or .6−
32149440
5997120

(*b*)

8	64	$\sqrt[3]{.523'600'000} = .80599+$ or $.8060-$
8	128	512 Ans.
16	1920000	11600000
8	12025	9660125
2400	1932025	1944075)1939875.00(.99
5	12050	17496675
2405	1944075	1902075
5		
2410		

(159) $11.7 : 13 :: 20 : x.$ The product of the means equals the product of the extremes.

$$11.7\,x = 13 \times 20$$
$$11.7\,x = 260$$

$$x = \frac{260}{11.7}$$

```
11.7 ) 260.000 ( 22.22+   Ans.
       234
        260
        234
         260
         234
          260
          234
           26
```

(160) (*a*) $20 + 7 : 10 + 8 :: 3 : x.$

$$27 : 18 :: 3 : x$$
$$27\,x = 18 \times 3$$
$$27\,x = 54$$
$$x = \frac{54}{27} = 2.\quad \text{Ans.}$$

(*b*) $12^2 : 100^2 :: 4 : x.$

$$144 : 10{,}000 :: 4 : x$$
$$144\,x = 10{,}000 \times 4$$
$$144\,x = 40{,}000$$

$$x = \frac{40,000}{144}$$

```
144 ) 40000.0 ( 277.7 +   Ans.
      288
      1120
      1008
       1120
       1008
        1120
        1008
         112
```

(161) (*a*) $\frac{4}{x} = \frac{7}{21}$, is equivalent to $4 : x :: 7 : 21$. The product of the means equals the product of the extremes Hence,

$$7x = 4 \times 21$$
$$7x = 84$$
$$x = \frac{84}{7} \text{ or } 12. \quad \text{Ans.}$$

(*b*) In like manner,

$\frac{x}{24} = \frac{8}{16}$ is equivalent to $x : 24 :: 8 : 16$.

$$16x = 24 \times 8$$
$$16x = 192$$
$$x = \frac{192}{16} = 12. \quad \text{Ans.}$$

(*c*) $\frac{2}{10} = \frac{x}{100}$ is equivalent to $2 : 10 :: x : 100$.

$$10x = 2 \times 100$$
$$10x = 200$$
$$x = \frac{200}{10} = 20. \quad \text{Ans.}$$

(*d*) $\frac{15}{45} = \frac{60}{x}$ is equivalent to

$15 : 45 :: 60 : x$.

$$15x = 45 \times 60$$
$$15x = 2,700$$
$$x = \frac{2,700}{15} = 180.$$

Ans.

(*e*) $\frac{10}{150} = \frac{x}{600}$ is equivalent to

$10 : 150 :: x : 600$.

$$150x = 10 \times 600$$
$$150x = 6,000$$
$$x = \frac{6,000}{150} = 40. \quad \text{Ans.}$$

(162) $x : 5 :: 27 : 12.5.$

$$\begin{array}{l} \quad 5 \\ 12.5\,)\,135.0\,(\,10\tfrac{4}{5} \text{ Ans.} \\ \quad 125 \\ \quad \overline{100} \end{array} \qquad \frac{100}{125} = \frac{4}{5}$$

(163) $45 : 60 :: x : 24$

$60x = 45 \times 24$

$60x = 1{,}080$

$x = \frac{1{,}080}{60} = 18.$ Ans.

(164) $x : 35 :: 4 : 7.$

$7x = 35 \times 4$

$7x = 140$

$x = \frac{140}{7} = 20.$ Ans.

(165) $9 : x :: 6 : 24.$

$6x = 9 \times 24$

$6x = 216$

$x = \frac{216}{6} = 36.$ Ans.

(166)

$\sqrt[3]{1{,}000} : \sqrt[3]{1{,}331} :: 27 : x.$

$10 : 11 :: 27 : x.$

$10x = 297.$

$x = \frac{297}{10} = 29.7.$ Ans.

$\sqrt[3]{1{,}000} = 10.$

$\sqrt[3]{1{,}331} = 11.$

$$\begin{array}{r} 1 \\ 1 \\ \hline 2 \\ 1 \\ \hline 30 \\ 1 \\ \hline 31 \end{array} \qquad \begin{array}{r} 1 \\ 2 \\ \hline 300 \\ 31 \\ \hline 331 \end{array} \qquad \begin{array}{r} 1'331\,(\,11 \\ 1 \\ \hline 331 \\ 331 \\ \hline \end{array}$$

(167) $64 : 81 = 21^2 : x^2.$

Extracting the square root of each term of any proportion does not change its value, so we find that $\sqrt{64} : \sqrt{81} = \sqrt{21^2} : \sqrt{x^2}$ is the same as

$8 : 9 = 21 : x$

$8x = 189$

$x = 23.625.$ Ans.

(168) $7 + 8 : 7 = 30 : x$ is equivalent to

$15 : 7 = 30 : x.$

$15x = 7 \times 30$

$15x = 210$

$x = \frac{210}{15} = 14.$ Ans.

(169) 2 ft. 5 in. = 29 in.; 2 ft. 7 in. = 31 in. Stating as a direct proportion, $29 : 31 = 2{,}480 : x$. Now, it is easy to see that x will be greater than 2,480. But x should be less than 2,480, since, when a man lengthens his steps, the number of steps required for the same distance is less; hence, the proportion is an inverse one, and

$$29 : 31 = x : 2{,}480,$$
or, $$31x = 71{,}920;$$
whence, $x = 71{,}920 \div 31 = 2{,}320$ steps. Ans.

(170) This is evidently a direct proportion. 1 hr. 36 min. = 96 min.; 15 hr. = 900 min. Hence,

$$96 : 900 = 12 : x,$$
or, $$96x = 10{,}800;$$
whence, $x = 10{,}800 \div 96 = 112.5$ mi. Ans.

(171) This is also a direct proportion; hence,

$$27.63 : 29.4 = .76 : x,$$
or, $$27.63x = 29.4 \times .76 = 22.344;$$
whence, $x = 22.344 \div 27.63 = .808 +$ lb. Ans.

(172) 2 gal. 3 qt. 1 pt. = 23 pt.; 5 gal. 3 qt. = 46 pt. Hence,

$$23 : 46 = 5 : x,$$
or, $$23x = 46 \times 5 = 230;$$
whence, $x = 230 \div 23 = 10$ days. Ans.

(173) Stating as a direct proportion, and squaring the distances, as directed by the statement of the example, $6^2 : 12^2 = 24 : x$. Inverting the second couplet, since this is an inverse proportion,

$$6^2 : 12^2 = x : 24.$$

Dividing both terms of the first couplet by 6

$1^2 : 2^2 = x : 24$; or $1 : 4 = x : 24$;
whence, $4x = 24$, or $x = 6$ degrees. Ans.

(174) $24\ \%$ of $\$950 = 950 \times .24 = \$228$
$12\frac{1}{2}\%$ of $\$950 = 950 \times .125 = 118.75$
$17\ \%$ of $\$950 = 950 \times .17 = 161.50$

$53\frac{1}{2}\%$ of $\$950 = \$508.25$

The total amount of his yearly expenses, then, is $508.25; hence, his savings are $\$950 - \$508.25 = \$441.75$. Ans.

Or, as above, $24\% + 12\frac{1}{2}\% + 17\% = 53\frac{1}{2}\%$, the total percentage of expenditures; hence,

$$\$950 \times .535 = \$508.25, \text{ and}$$
$$\$950 - \$508.25 = \$441.75 = \text{his yearly savings. Ans.}$$

(175) Here $1,125 is 30% of some number; hence, $1,125 = the percentage, 30% = the rate, and the required number is the base.

$$\text{Base} = \text{percentage} \div \text{rate}$$
$$= \$1,125 \div .30 = \$3,750.$$

Since $3,750 is $\frac{3}{4}$ of the property, one of the fourths is $\frac{1}{3}$ of $\$3,750 = \$1,250$, and 4 fourths, or the entire property, is $4 \times \$1,250 = \$5,000$. Ans.

(176) The volume of water raised is 18.3 cu. in.; the volume of water lost is 254.5 cu. in.; hence, the total volume passing through the drive pipe is $18.3 + 254.5 = 272.8$ cu. in. It is required to find what per cent. 18.3 is of 272.8. Here 272.8 is the base, 18.3 is the percentage, and the rate to be found = percentage ÷ base $= 18.3 \div 272.8 = .0671$, nearly = 6.71%. Ans.

```
272.8 ) 18.30000 (.0671, nearly, or 6.71%.  Ans.
        16368
        -----
         19320
         19096
         -----
          2240
```

(177) As stated, the velocity of the water when the valve is partly opened is 298 ft. per min. If, by opening the

valve a little further, the velocity is increased $1\frac{1}{2}\%$, then the increase must equal $.01\frac{1}{2} \times 298 = 4.47$ ft., and the final velocity must equal 298 ft. + 4.47 ft. = 302.47 ft. per min. Ans.

$$\begin{array}{r} 298 \text{ ft.} \\ .015 \\ \hline 1490 \\ 298 \\ \hline 4.470 \text{ ft.} \end{array} \qquad \begin{array}{r} 298.00 \text{ ft.} \\ 4.47\phantom{\text{ ft.}} \\ \hline 302.47 \text{ ft.} \end{array} \quad \text{Ans.}$$

(178) 5 ft. $3\frac{1}{2}$ in. reduced to inches equals $63\frac{1}{2}$, or 63.5 in.

$$\begin{array}{rl} \text{ft.} & \text{in.} \\ 5 & 3\frac{1}{2} \\ \times\ 12 & \\ \hline 60 & \\ +\ 3.5 & \\ \hline 63.5 \text{ in.} & \end{array}$$

$$\begin{array}{r} 63.5 \\ 37 \\ \hline 4445 \\ 1905 \\ \hline 2349.5 \text{ in.} \end{array}$$

Since one length of pipe measures 63.5 in., it is evident that 37 lengths would measure 37 times as much, or 2,349.5 in.

Since the slip of the hub is 3 in., the total allowance to be made equals 36×3, or 108 in., which, deducted from the total length of the pipe, equals 2,241.5 in.

$$\begin{array}{r} 2349.5 \text{ in.} \\ -\quad 108\phantom{.5 \text{ in.}} \\ \hline \end{array}$$

$$\begin{array}{l} 12)\,2241.5 \text{ in.}\,(186 \text{ ft. } 9.5 \text{ in.} \quad \text{Ans.} \\ 12 \\ \overline{104} \\ 96 \\ \overline{81} \\ 72 \\ \overline{9.5} \end{array}$$

Reducing 2,241.5 in. to feet by dividing by 12, we have 186 ft. $9\frac{1}{2}$ in. Ans.

(179) 9 ft. 4 in. reduced to inches equals 112 in. Since the depth of each socket is $3\frac{1}{2}$ in. and the length of each pipe over all is 112 in., then the length of each pipe must equal 112 in. $-$ $3\frac{1}{2}$ in. $=$ $108\frac{1}{2}$ or 108.5 in.

$$\begin{array}{r} 9 \text{ ft. } 4 \text{ in.} \\ \times \underline{\quad 12} \\ 108 \\ + \underline{\quad 4} \\ 112 \text{ in.} \end{array}$$

Reducing 1 mi. and 1,980 ft. to inches, we have 87,120 in. There are 5,280 ft. in 1 mile and there are 12 in. in 1 ft.; hence in 5,280 ft., or 1 mile, there are $12 \times 5{,}280$ or 63,360 in. 1,980 ft. $\times 12 =$ 23,760 in., which, added to 63,360, makes a total of 87,120 in.

$$\begin{array}{r} 23760 \text{ in.} \\ + \underline{63360} \\ 87120 \text{ in.} \end{array}$$

If each pipe is 108.5 in. in length, to lay a street main 87,120 in. in length, it would require as many pipes as 108.5 is contained times in 87,120, or 803 pipes, nearly. Ans.

$$\begin{array}{l} 108.5)\,87120.0\,(803, \text{ nearly. Ans.} \\ \underline{8680} \\ 3200 \\ \underline{3255} \end{array}$$

(180) From the conditions stated in the problem, we find that the total length of the pipe equals 87 ft. 2 in.

ft.	in.
15	5
15	5
15	5
15	5
14	8
10	10
84	38 or
87	2

$$\begin{array}{r} 87 \text{ ft. } 2 \text{ in.} \\ \times \underline{\quad 12} \\ 174 \\ \underline{87} \\ 1044 \\ + \underline{\quad 2} \\ 1046 \text{ in.} \end{array}$$

Reducing 87 ft. 2 in. to inches, we have 1,046 inches. Since one of the pipe hangers is placed a foot from each end, the length of the pipe will equal 1,046 in. $-$ 24 in. or 1,022 inches.

(1 ft. from each end equals 2 ft., or 24 in., to be deducted as above.)

Since there are 12 hangers there will be 11 spaces. We wish to find the distance between the hangers or the length of one of the spaces. This we do by dividing by 11.

$$
\begin{array}{l}
11)\,1022 \text{ in. } (92, \text{ or } 93 \text{ in., nearly.} \\
\quad\;\; \underline{99} \\
\quad\;\;\; 32 \\
\quad\;\;\; \underline{22} \\
\quad\;\;\; 10
\end{array}
$$

$$
\begin{array}{l}
12)\,\underline{93 \text{ in.}} \\
\quad\; 7 \text{ ft. } 9 \text{ in. Ans.}
\end{array}
$$

Since 12 in. equals 1 ft., 93 in. = 7 ft. 9 in., nearly, or the distance between the hangers. Ans.

(181) Since the distance around a cedar tank (its base being circular) is $\frac{22}{7}$ times the distance across it, then the distance around the tank will be (9 ft. $6\frac{1}{2}$ in.) $\times \frac{22}{7}$.

$$
\begin{array}{rl}
\text{ft.} & \text{in.} \\
9 & 6\frac{1}{2} \\
\times\ \underline{12} & \\
108 & \\
+\ \underline{\quad 6\frac{1}{2}} & \\
114\frac{1}{2} &
\end{array}
$$

9 ft. $6\frac{1}{2}$ in. = $114\frac{1}{2}$ in.

Reducing $114\frac{1}{2}$ to an improper fraction $= \frac{229}{2}$.

Multiplying, $\frac{229}{\cancel{2}} \times \frac{\overset{11}{\cancel{22}}}{7} = \frac{2,519}{7} = 359\frac{6}{7}$ in.

Dividing by 12 to reduce to feet, we have 29 ft. $11\frac{6}{7}$ in.

$$
\begin{array}{l}
12)\,359\frac{6}{7}\,(29 \text{ ft. } 11\frac{6}{7} \text{ in.} \\
\quad\; \underline{24} \\
\quad\; 119 \\
\quad\; \underline{108} \\
\quad\;\; 11\frac{6}{7}
\end{array}
$$

(182) Reducing 18 ft. $11\frac{1}{4}$ in. to inches, we have $18 \times 12 = 216$. $216 + 11\frac{1}{4} = 227\frac{1}{4}$ in. $1\frac{1}{8}$ in. $\times 2 = 2\frac{1}{4}$ in. for the

two end rivets, which being deducted from $227\frac{1}{4}$ in., the total length, equals 225 in., which is divided into *equal* spaces by the rivets.

$2\frac{1}{4} = 2.25.$

$$
\begin{array}{r}
2.25)\,225.00\,(100 \text{ spaces.} \\
\underline{125}\phantom{00\,(100 \text{ spaces.}} \\
1000\phantom{\,(100 \text{ spaces.}} \\
\underline{1000}\phantom{\,(100 \text{ spaces.}} \\
0\phantom{\,(100 \text{ spaces.}}
\end{array}
$$

We find that the number of spaces equals 100, and since there will be one more rivet than the number of spaces, the number of rivets required would be $100 + 1 = 101$. Ans.

(183) This is an *inverse* ratio, since it will take a pump discharging 85 gal. per minute a *longer* time to fill the tank than one discharging 135 gal. per minute. The direct proportion would be

$$135 \text{ gal.} : 85 \text{ gal.} :: 38 \text{ min.} : x \text{ min.}$$

In order to make the proportion inverse, we must invert one of the couplets, and we have

$$135 : 85 :: x : 38$$
$$85x = 135 \times 38$$
$$85x = 5{,}130$$
$$x = \frac{5{,}130}{85} = 60\tfrac{6}{17} \text{ min.} \quad \text{Ans.}$$

$$
\begin{array}{r}
135 \\
\times\ 38 \\
\hline
1080 \\
405 \\
\hline
85)\,5130\,(60\tfrac{6}{17} \\
510 \\
\hline
30 \\
\end{array}
\qquad \frac{30}{85} = \frac{6}{17}
$$

(184) $8 \text{ lb.} + 8 \text{ lb.} + 80 \text{ lb.} = 96 \text{ lb.}$, or the number of pounds in the mixture. The relation between the amount of copper which 32 lb. of this mixture will contain and the amount which 96 lb. contain is the same as $32 : 96$; whence, the proportion $32 \text{ lb.} : 96 \text{ lb.} :: x : 8 \text{ lb.}$

Since in every proportion the product of the means equals the product of the extremes, we have

$$96x = 32 \times 8$$
$$96x = 256$$
$$x = \frac{256}{96} = 2\tfrac{2}{3} \text{ lb.} \quad \text{Ans.}$$

$$
\begin{array}{r}
96)256(2 \\
\underline{192} \\
\frac{64}{96} = \frac{2}{3}
\end{array}
$$

(185) The larger steam pump discharges 49.087 cu. in. of water with each stroke of the piston in the same time that the smaller steam pump discharges 31.416 cu. in. under the same conditions. We wish to find how many strokes the larger pump must make in order to fill a tank which the smaller pump fills during 520 strokes. It is evident that the number of strokes the larger pump makes bears the same relation to the number of strokes that the smaller pump makes that 31.416 cu. in. bears to 49.087 cu. in. Letting x occupy any place in the proportion, we have the following, the value of x being the same in each:

(*a*) 49.087 cu. in. : 31.416 cu. in. :: 520 strokes : x strokes,

$$\text{or } x = \frac{31.416 \times 520}{49.087} = \frac{16,336.32}{49,087} = 333 \text{ strokes, nearly.}$$

$$
\begin{array}{r}
31.416 \\
\times \quad 520 \\
\hline
628320 \\
157080 \\
\hline
49.087)16336.320(333- \\
147261 \\
\hline
161022 \\
147261 \\
\hline
137610 \\
147261 \\
\hline
\end{array}
$$

(*b*) 31.416 cu. in. : 49.087 cu. in. :: x strokes : 520 strokes,

$$\text{or } x = \frac{31.416 \times 520}{49.087} = 333 \text{ strokes.}$$

(*c*) x strokes : 520 strokes :: 31.416 cu. in. : 49.087 cu. in.,

$$\text{or } x = \frac{31.416 \times 520}{49.087} = 333 \text{ strokes.}$$

(*d*) 520 strokes : x strokes :: 49.087 cu. in. : 31.416 cu. in.,

$$\text{or } x = \frac{31.416 \times 520}{49.087} = 333 \text{ strokes. Ans.}$$

(186) Before forming the proportion, we will combine the three simple ratios into one by reducing them all to the same denomination. A cistern 28 feet long, 12 feet wide, and 10 feet deep contains $28 \times 12 \times 10 = 3{,}360$ cubic feet. Again, a cistern 20 ft. long, 17 ft. wide, and 6 ft. deep contains $20 \times 17 \times 6 = 2{,}040$ cubic feet. What do we wish to find? In this case it is "barrels." We know that a cistern containing 3,360 cubic feet holds 798 barrels of water, and we want to know how many barrels of water a cistern containing 2,040 cubic feet will hold. The number of barrels that a cistern containing 2,040 cubic feet will hold bears the same relation to the number of barrels that a cistern containing 3,360 cubic feet holds as 2,040 cubic feet bears to 3,360 cubic feet. Hence,

2,040 cu. ft. : 3,360 cu. ft. :: x bbl. : 798 bbl.,

$$\text{or} \quad x = \frac{\overset{85}{\cancel{2{,}040}} \times \overset{57}{\cancel{798}}}{\underset{\underset{10}{\cancel{140}}}{\cancel{3{,}360}}} = \frac{85 \times 57}{10} = 484.5 = 484\tfrac{1}{2} \text{ bbl.} \quad \text{Ans.}$$

(187) The weight of a piece of cast-iron pipe $6\frac{3}{4}$ ft. long bears the same relation to the weight of a piece of pipe $3\frac{1}{2}$ ft. long as $6\frac{3}{4}$ bears to $3\frac{1}{2}$. Since ratio is the measure of

relation, we can express the above in a proportion as follows, first reducing the different terms to decimals:

$$6\tfrac{3}{4} = 6.75. \quad 3\tfrac{1}{2} = 3.5.$$

(*a*) 6.75 ft. : 3.5 ft. :: x lb. : 37.45 lb.

Since in every proportion the product of the means equals the product of the extremes, we have

$$3.5\,x = 6.75 \times 37.45.$$
$$3.5\,x = 252.7875.$$
$$x = \frac{252.7875}{3.5} = 72.225 \text{ lb.} \quad \text{Ans.}$$

(*b*) 3.5 ft. : 6.75 ft. :: 37.45 lb. : x lb.,

$$\text{or } x = \frac{252.7875}{3.5} = 72.225 \text{ lb.} \quad \text{Ans.}$$

(*c*) 37.45 lb. : x lb. :: 3.5 ft. : 6.75 ft.,

$$\text{or } x = \frac{252.7875}{3.5} = 72.225 \text{ lb.} \quad \text{Ans.}$$

(*d*) x lb. : 37.45 lb. :: 6.75 ft. : 3.5 ft.,

$$\text{or } x = \frac{252.7875}{3.5} = 72.225 \text{ lb.} \quad \text{Ans.}$$

(188) We will first reduce 8 hr. 40 min. to minutes. 8 hr. + 40 min. = (8 × 60 min.) + 40 min. = 520 min. In this problem we are required to find "time." We know that a hydraulic ram whose capacity is 444 gallons fills a tank in 520 minutes, and we want to know how long it will take it to fill a tank whose capacity is 1,060 gallons. It is evident that the time it requires to fill a tank containing 1,060 gallons bears the same relation to the time it takes to fill a tank containing 444 gallons that 1,060 gallons bears to 444 gallons. Letting x occupy any place in the proportion, we have the following, the value of x being the same in each. Thus,

(*a*) 1,060 gallons : 444 gallons :: x min. : 520 min.,

$$\text{or } x = \frac{1,060 \times 520}{444} = \frac{551,200}{444} =$$

```
  1060
   520
 ------
 21200
5300
 ------
551200
```

```
444)551200.00(1241.44+ min.
    444
    ---
    1072
     888
    ----
     1840
     1776
     ----
       640
       444
       ---
       1960
       1776
       ----
        1840
        1776
        ----
          64
```

Reducing 1,241.44 min. to hours by dividing by 60, we have

```
60)1241.44(20 hr. 41.44 min.   Ans.
   120
   ---
    41.44
```

(*b*) 444 gallons : 1,060 gallons :: 520 min. : x min.

$$x = \frac{1,060 \times 520}{444} = 1,241.44 \text{ min., or } 20 \text{ hr. } 41.44 \text{ min.} \quad \text{Ans.}$$

(*c*) x min. : 520 min. :: 1,060 gallons : 444 gallons.

$$x = \frac{1,060 \times 520}{444} = 1,241.44 \text{ min., or } 20 \text{ hr. } 41.44 \text{ min.} \quad \text{Ans.}$$

(*d*) 520 min : x min. :: 444 gallons : 1,060 gallons.

$$x = \frac{1,060 \times 520}{444} = 1,241.44 \text{ min., or } 20 \text{ hr, } 41.44 \text{ min.} \quad \text{Ans.}$$

MENSURATION AND USE OF LETTERS IN FORMULAS.

(QUESTIONS 189–267.)

(189) Substituting for D, x, B, and i their values,

$$C = \frac{D - x}{B + i} = \frac{120 - 12}{10 + 3.5} = \frac{108}{13.5} = 8. \quad \text{Ans.}$$

A line between two numbers signifies that the one above the line, or numerator, is to be divided by the one below the line, or denominator.

(190) Substituting for A, h, D, and x their values,

$$\frac{A\,h + D}{2x + 6} = \frac{(5 \times 200) + 120}{(2 \times 12) + 6} = \frac{1{,}000 + 120}{24 + 6} = \frac{1{,}120}{30} = 37\tfrac{1}{3}.$$

$$37\tfrac{1}{3} + D = 37\tfrac{1}{3} + 120 = 157\tfrac{1}{3}. \quad \text{Ans.}$$

When there is no sign between the letters, multiplication is understood.

(191) Substituting for B, h, A, x, and i their values,

$$r = \frac{3.246 \times B \times h}{\dfrac{A\,x + h}{A\,i - B}} = \frac{3.246 \times 10 \times 200}{\dfrac{(5 \times 12) + 200}{(5 \times 3.5) - 10}} = \frac{6{,}492}{\dfrac{260}{7.5}} =$$

$$6{,}492 \div \frac{260}{7.5} = 6{,}492 \times \frac{7.5}{260} = 187.269 +. \quad \text{Ans.}$$

(192) Substituting for A, D, i, and B their values,

$$v = \sqrt{\frac{A\,D}{i\,B + 1.5}} = \sqrt{\frac{5 \times 120}{(3.5 \times 10) + 1.5}} = \sqrt{\frac{600}{36.5}} =$$

$$\sqrt{16.4383} = 4.05 +. \quad \text{Ans.}$$

The square root sign extends over both numerator and denominator, thus indicating that the square root of the entire fraction is to be extracted.

(193) Substituting for B, x, h, and A their values,

$$u = \sqrt[3]{\frac{B\,x}{.00018\,h\,(A^2 - x)}} = \sqrt[3]{\frac{10 \times 12}{.00018 \times 200 \times (5^2 - 12)}} =$$

$$\sqrt[3]{\frac{120}{.036 \times (25 - 12)}} = \sqrt[3]{\frac{120}{.036 \times 13}} = \sqrt[3]{\frac{120}{.468}} =$$

$$\sqrt[3]{256.41} + = 6.35 +. \quad \text{Ans.}$$

(194) Substituting for h, D, and A their values,

$$f = \frac{10\,(h - D)^2}{\sqrt[3]{D + A}} = \frac{10\,(200 - 120)^2}{\sqrt[3]{120 + 5}} = \frac{10 \times 80^2}{\sqrt[3]{125}} = \frac{64{,}000}{5} = 12{,}800. \quad \text{Ans.}$$

(195) Substituting for B, A, and D their values,

$$g = \frac{(B - A)^2 - \sqrt[3]{D + A}}{A^3 - (1 + D)} = \frac{(10 - 5)^2 - \sqrt[3]{120 + 5}}{5^3 - (1 + 120)} =$$

$$\frac{5^2 - \sqrt[3]{125}}{125 - 121} = \frac{25 - 5}{4} = \frac{20}{4} = 5. \quad \text{Ans.}$$

(196) Substituting for A, B, and h their values,

$$k = \sqrt{\frac{A\,B^2}{\sqrt[3]{A\,h}}} = \sqrt{\frac{5 \times 10^2}{\sqrt[3]{5 \times 200}}} = \sqrt{\frac{5 \times 100}{\sqrt[3]{1{,}000}}} = \sqrt{\frac{500}{10}} =$$

$$\sqrt{50} = 7.071 +. \quad \text{Ans.}$$

(197) Substituting for A, h, D, x, and B their values,

$$T = \sqrt{\frac{A^2\left[490 + \frac{(h\,x)^2}{D^2}\right]}{h + \frac{x}{D}\,(A^2 - B)^2}} = \sqrt{\frac{5^2\left[490 + \frac{(200 \times 12)^2}{120^2}\right]}{200 + \frac{12}{120}\,(5^2 - 10)^2}} =$$

$$\sqrt{\frac{25\,(490 + 400)}{200 + (\frac{1}{10} \times 225)}} = \sqrt{\frac{25 \times 890}{200 + 22.5}} = \sqrt{\frac{22{,}250}{222.5}} =$$

$$\sqrt{100} = 10. \quad \text{Ans.}$$

(198) When one straight line meets another straight line, two angles are formed which together equal 180°. Hence, if one of the angles = 152° 3′, the other angle = 180° − 152° 3′, or

	180° = 179° 60′
subtracting	152° 3′
	27° 57′. Ans.

(199) There are 60 seconds in one minute and 60 minutes in one degree; therefore, $140° = 140 \times 60 = 8,400$ minutes; $8,400' + 17' = 8,417'$; $8,417' = 8,417 \times 60 = 505,020$ seconds, and $505,020'' + 10'' = 505,030''$. Ans.

(200) See Art. **359.**

(201) (*a*) $240 \div 60 = 4$, the number of degrees. Ans.

(*b*) $240 \times 60 = 14,400$, the number of seconds. Ans.

(202) See Arts. **355** to **357.**

(203) See Art. **369.** If the rectangle has the same base and altitude, it would have the same area.

(204) No, since the sum of the three shorter sides is not greater than the fourth side.

(205) Since the area is to be found in square inches, the $2\frac{1}{2}$ feet must be reduced to inches. $2\frac{1}{2}$ ft. = 30 in. Area = $30 \times 11\frac{1}{2} = 345$ sq. in. Ans.

(206) (*a*) Area $= 25.7 \times 6.75 = 173.475$ sq. ft. Ans.

(*b*) Weight = 6.5 lb. per sq. ft. $= 173.475 \times 6.5 = 1,127.5875$ lb. = 11 cwt. 27.5875 lb. Ans.

(*c*) Cost = $6\frac{1}{4}$ cents per pound = .0625 dollar when reduced to the decimal part of a dollar. Hence, total cost = $1,127.5875 \times .0625 = \$70.47$. Ans.

(207) (*a*) The area of the base is most conveniently found in square feet, and of the side, in square inches. 6 ft. 3 in. = 6.25 ft.; 4 ft. 6 in. = 4.5 ft.; area of bottom = $6.25 \times 4.5 = 28.125$ sq. ft. The area of the sides = distance around bottom × depth of tank. The box is 75 in. long and 54 in. wide; distance around bottom $= 2 \times 75 + 2 \times 54 = 150 + 108 = 258$ in.; depth in inches = 44; hence, area of sides $= 258 \times 44 = 11,352$ sq. in. To this must be added the area of the metal turned over at the top, which $= 258 \times 1 = 258$ sq. in.; $11,352 + 258 = 11,610$ sq. in.; this reduced to square feet $= 11,610 \div 144 = 80.625$. Therefore, total amount of metal used $= 28.125 + 80.625 = 108.75$ sq. ft. Ans.

(*b*) Weight of metal on bottom = 28.125 × 6.5 = 182.8125 lb. Ans.

Weight of metal on sides = 80.625 × 5.5 = 443.4375 lb. Ans.

(*c*) Deducting 4 in. from the depth of the tank, 3 ft. 8 in. − 4 in. = 3 ft. 4 in. = $3\frac{1}{3}$ ft. Volume in cubic feet = area of bottom × depth = 28.125 × $3\frac{1}{3}$ = 93.75 cu. ft., which is equivalent to 93.75 × 7.48 = 701.25 gal. Ans.

(208) By the rule for the area of a trapezoid, area of the sheet iron = $\frac{4.32 + 5.48}{2} \times 2.18 = 4.9 \times 2.18 = 10.682$ sq. ft. Ans.

(209) (*a*) Sectional area of inside of tube = 9.5 × 5.5 = 52.25 sq. in. Ans.

(*b*) Since the sides are ½ in. thick, the outside dimensions are 9.5 + 1 = 10.5 in., and 5.5 + 1 = 6.5 in. Hence, the area of one end of the tube, outside measure = 10.5 × 6.5 = 68.25 sq. in. The sectional area of the metal is the difference between the outside and inside areas, or 68.25 − 52.25 = 16 sq. in. Ans.

(*c*) First find the number of cubic inches in the pipe by the rule for the volume of a prism. In this case the area of one end, or the base, = 16 sq. in.; the altitude, or length, = 9 ft. 3 in. = 111 in.; number of cubic inches = 16 × 111 = 1,776; weight = 1,776 × .24 = 426.24 lb. Ans

(210) Since all the sides of a cube are alike, we have here the bottom and four sides to be covered, all of which are 4 ft. square. Hence, area to be covered = 4 × 4 × 5 = 80 sq. ft. Cost = 80 × .56 = $44.80. Ans.

(211) Neglecting at first the spaces to be deducted, we have area of floor = 15 × 20 = 300 sq. ft.; area of surfaces of walls that are to be covered = distance around room × 5 = (20 × 2 + 15 × 2) × 5 = 350 sq. ft.

From these two areas, which together equal $300 + 350 = 650$ sq. ft., are to be taken

area of bath	$= 5 \times 12 =$	60 sq. ft.
area of 5 ft. of door	$= 5 \times 3 =$	15 sq. ft.
area of 3 ft. of window	$= 3 \times 4 =$	12 sq. ft.
Amount to be deducted $=$		87 sq. ft.

$650 - 87 = 563$ sq. ft., the surface to be covered by the tiles. Since the tiles are 6 in. square, four tiles are required for each square foot. Hence, the number of tiles required $= 563 \times 4 = 2{,}252$. Ans.

(212) (*a*) The contents of the lead in cubic inches are $36 \times 24 \times 1 = 864$ cu. in. When rolled out, the surface of the lead contained $240 \times 72 = 17{,}280$ sq. in. Its volume remains the same, however, since no lead is lost in the operation, and its thickness must be such a number that, when 17,280 sq. in. are multiplied by it, the product will be 864 cu. in. To obtain the thickness, therefore, divide 864 by 17,280, which gives .05, or $\frac{1}{20}$ of an inch. Ans.

(*b*) This bar will still have the same volume, or 864 cu. in. The area of one end $= 6 \times 3 = 18$ sq. in., and the length $= \frac{864}{18} = 48$ in., or 4 ft. Ans.

(*c*) Weight $= 864 \times .41 = 354.24$ lb. Ans.

(213) (*a*) The tube has four sides, of which the two longer together $= 8 + 8 = 16$ in.; the two shorter sides, therefore, together $= 24 - 16 = 8$ in., and one of the shorter sides $= 8 \div 2$ or 4 in. Hence, sectional area $= 8 \times 4 = 32$ sq. in. Ans.

(*b*) Perimeter doubled $= 24 \times 2 = 48$ in.; $10 \times 2 = 20$ in., the length of the two given sides taken together; $48 - 20 = 28$ in., the length of the other sides taken together; $28 \div 2 = 14$, and $14 \times 10 = 140$ sq. in. Ans.

(214) A triangle with three equal angles has three equal sides, and is, therefore, an equilateral triangle.

(215) A triangle with two equal angles has two equal sides, and is, therefore, an isosceles triangle.

(216) No, since the sum of the two shorter sides is not greater than the third side.

(217) (*a*) Draw a line BD from the vertex perpendicular to the base. (Fig. 1.) It will divide the base into two equal parts, as shown. In the right-angled triangle ABD, the hypotenuse $AB = 6$, and side $AD = 3$; hence, BD, the altitude $= \sqrt{6^2 - 3^2} = \sqrt{27} = 5.196$ ft. Ans.

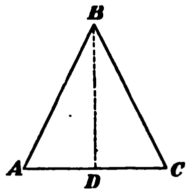

FIG. 1.

(*b*) $\text{Area} = \dfrac{6 \times 5.196}{2} = 15.588$ sq. ft. Ans.

(218) The sum of the three angles in any triangle = 2 right angles, or 180°. In the given triangle, the sum of two angles $= 23° + 32° \; 32' = 55° \; 32'$, and the third angle $= 180° - 55° \; 32'$, or

$$\begin{array}{rr} 180° = & 179° \; 60' \\ \text{subtracting} & 55° \; 32' \\ \hline & 124° \; 28'. \end{array} \quad \text{Ans.}$$

(219) In Fig. 2, we have the proportion $AD : DE :: AB : BC$, in which $AD = 10$ in., $AB = 24$ in., and $BC = 13\frac{1}{2}$ in., to find DE.

Substituting the given values,

$$10 : DE :: 24 : 13\tfrac{1}{2}, \text{ or}$$

$$DE = \frac{10 \times 13.5}{24} = 5.625 \text{ in. Ans.}$$

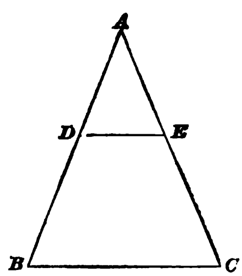

FIG. 2.

(220) The distance across the field from corner to corner is found by the rule for obtaining the hypotenuse when the two sides are given. Hence, the estimated length for the pipe was $\sqrt{300^2 + 300^2} = \sqrt{180,000} = 424.26$ yd. The actual length was $300 + 300 = 600$ yd. Difference $= 600 - 424.26$ yd. $=$ 175 yd. 2 ft. 2 in. +. Ans.

(221) By the rule for finding one side of a triangle when the hypotenuse and other side are given, the required distance $= \sqrt{24^2 - 8^2} = \sqrt{576 - 64} = 22.627$ ft. $= 22$ ft. $7\frac{1}{2}$ in. + Ans.

(222) See Art. **386.**

(223) (*a*) Length of base $= \frac{2 \times 200}{20} = 20$ in. Ans.

(*b*) A perpendicular let fall from the vertex to the base will divide the triangle into two equal right-angled triangles, of which the perpendicular side is 20 inches and the horizontal side 10 inches. Hence, the hypotenuse $= \sqrt{20^2 + 10^2} =$ 22.36 in. = the length of one of the equal sides of the given triangle. Ans.

(224) An equilateral heptagon has seven equal sides; hence, the sum of all the sides, or the perimeter, $= 7 \times 3 =$ 21 in. Ans.

(225) A regular decagon has 10 equal sides; hence, the length of one of the sides $= 40 \div 10 = 4$ inches. Ans.

(226) A dodecagon has 12 sides, and by the rule for finding one of the angles of a regular polygon, we have 2 less than the number of sides $= 12 - 2 = 10$; $180° \times 10 =$ 1,800; 1,800 ÷ 12, the number of sides, $= 150°$. Ans.

(227) Divide the pentagon into five equal isosceles triangles, as shown in Fig. 3, by drawing a line from the center to each angle. The area of one of the triangles, as $A\,B\,C$, $= 43 \div 5 =$ 8.6 sq. in. We have given, therefore, the area and base $B\,C$ of the triangle $A\,B\,C$, to find its altitude $A\,D$. Hence, $A\,D = \frac{8.6 \times 2}{5} = 3.44$ in., the perpendicular distance from the center to one side. Ans.

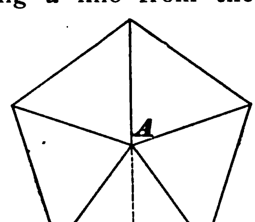

FIG. 3.

(228) This is done exactly like the example illustrated in Art. **389.** The process is simply to find one of the angles of the polygon, and then to divide it by 2. One of

the interior angles $= \frac{180 \times (8-2)}{8} = 135°$. This divided by $2 = 67\frac{1}{2}°$. Ans.

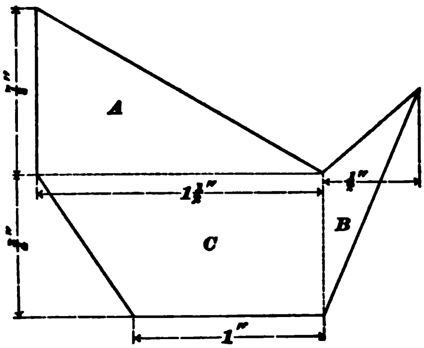

FIG. 4.

(229) Divide the figure into two triangles and one trapezoid, as shown in Fig. 4. The dimensions of the different parts can then be found by measurement. In obtaining the areas, it will be easier to use decimals than common fractions.

$$\text{Area of triangle } A = \frac{1\frac{1}{2} \times \frac{7}{8}}{2} = \frac{1.5 \times .875}{2} = .656 \text{ sq. in.}$$

$$\text{Area of triangle } B = \frac{\frac{3}{4} \times \frac{1}{2}}{2} = \frac{.75 \times .5}{2} = .188 \text{ sq. in.}$$

Area of trapezoid $C = \frac{1\frac{1}{2} + 1}{2} \times \frac{3}{4} = \frac{1.5 + 1}{2} \times .75 = 1.25 \times .75 = .938$ sq. in.

Hence, the area of the whole figure $= .656 + .188 + .938 = 1.78 +$ sq. in. Ans.

(230) An angle inscribed in a circle is measured by one-half the intercepted arc. In this case the angle intercepts one-fourth the circumference, and is measured by one-eighth the circumference, or by $360° \times \frac{1}{8} = 45°$. Hence, there are $45°$ in the angle. Ans.

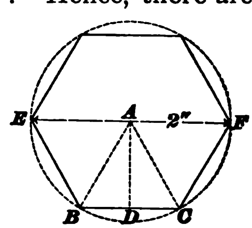

FIG. 5.

(231) Since this is a regular hexagon, it may be inscribed in a circle, and the radius of the inscribing circle will be equal to one side of the hexagon. Since the diameter $EF = 2$ inches (Fig. 5), the radii AB and AC and the side BC each $= 1$ inch, and the triangle ABC is equilateral

Draw the line $A D$ perpendicular to the side $B C$; it will bisect $B C$. Then, in the right-angled triangle $A D B$, $A B = 1$, and $B D = \frac{1}{2}''$, to find $A D$. $A D = \sqrt{1^2 - .5^2} = \sqrt{.75} = .866''$. Hence, the distance between two opposite sides of the hexagon $= A D \times 2 = .866 \times 2 = 1.732''$. Ans.

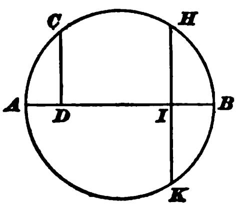
FIG. 6.

(232) In Fig. 6, we have the proportion $B I : H I :: H I : I A$, in which $B I = 6$, and $H I = \frac{1}{2}$ of $H K = \frac{18}{2} = 9$. Substituting, $6 : 9 :: 9 : I A$, or $I A = \frac{81}{6} = 13.5$ in. Hence, the diameter $A B = I A + B I = 13.5 + 6 = 19.5$ in. Ans.

(233) If the diameter $A B = 32\frac{1}{2}$ ft. and $I B = 8$ ft., $A I = 32\frac{1}{2} - 8 = 24\frac{1}{2}$ ft. Then, from the proportion of the last example, $8 : H I :: H I : 24.5$, whence, $H I = \sqrt{8 \times 24.5} = \sqrt{196} = 14$ ft., and $H K = 2 \times 14 = 28$ ft. Ans. (See Art. **400.**)

(234) Diameter = circumference $\div$ 3.1416. The circumference of the boiler = 50.2656 when reduced to inches. $50.2656 \div 3.1416 = 16$ in. = 1 ft. 4 in. Ans.

(235) (*a*) The length of wire required to go around the pipe once is equal to the circumference of the pipe, or $3 \times 3.1416 = 9.4248$ in. 20 ft. = 240 in., and the number of times that a wire 240 in. long would go around $= 240 \div 9.4248 = 25\frac{1}{2}$, nearly. Ans.

(*b*) Taking the thickness of the wire into consideration amounts to an addition of half the thickness of the wire to each side of the pipe, making the diameter of the pipe in effect $3\frac{1}{8}$ in.; $3\frac{1}{8} = 3.125$ when reduced to a decimal; $3.125 \times 3.1416 = 9.8175$ in.; $240 \div 9.8175 = 24\frac{1}{2}$, nearly. Ans.

(236) (*a*) $3\frac{1}{4}$ in. = 3.25 in. Area $= 3.25^2 \times .7854 = 8.2957$ sq. in. Ans.

(*b*) Circumference $= 3.25 \times 3.1416 = 10.2102$ in. Ans.

(237) (*a*) As the outside circumference = 14.137 in., the outside diameter $= 14.137 \div 3.1416 = 4.5$ in.; difference

between outside and inside diameter = 4.5 − 4.026 = .474 in.; thickness of pipe = .474 ÷ 2 = .237 in., nearly. Ans.

(*b*) The external surface is found in the same manner as the convex area of a cylinder. The outside circumference, which corresponds to the perimeter of the base of a cylinder, = 14.137 in.; 100 sq. ft. = 100 × 144 = 14,400 sq. in.; 14,400 ÷ 14.137 = 1,018.6 in., the length of pipe required corresponding to the altitude of a cylinder; 1,018.6 in. = 84.9 ft., nearly. Ans.

(238) Since the radius of the circle = 6 in., its diameter = 12 in., and circumference = 12 × 3.1416 = 37.6992 in. There are 360° in the circumference, and the length of an arc of $12° = 37.6992 \times \frac{12}{360} = 1.25664$ in. Ans.

(239) The area of a circle 22 inches in diameter = $22^2 \times .7854 = 380.1336$ sq. in. Area of a circle 21 inches in diameter = $21^2 \times .7854 = 346.3614$ sq. in. Hence, the area of a flat ring whose outside diameter = 22 in. and inside diameter = 21 in., is 380.1336 − 346.3614 = 33.7722 sq. in. Ans.

(240) (*a*) The stated diameters are the internal diameters of the pipe, and the areas of the heating surfaces are obtained as in Example 237 (*b*). Adding the thickness of the metal, the outside diameter of the 1-in. pipe = 1.25 in.; circumference = 1.25 × 3.1416 = 3.927 in.; length reduced to inches = 100 × 12 = 1,200 in.; heating surface = 3.927 × 1,200 = 4,712.4 sq. in. Outside diameter of 2-in. pipe = 2.25 in.; circumference = 2.25 × 3.1416 = 7.0686; heating surface of 2-in. pipe = 7.0686 × 1,200 = 8,482.32, and 8,482.32 − 4,712.4 = 3,769.92 sq. in. = 26.18 sq. ft. Ans.

(*b*) Heating surface of 200 ft. of 2-in. pipe = 8,482.32 × 2 = 16,964.64 sq. in.; heating surface of 1 ft. of 1-in. pipe = 3.927 × 12 = 47.124 sq. in.; 16,964.64 ÷ 47.124 = 360 ft. Ans.

(241) (*a*) Circumference of 1-in. pipe = 1.315 × 3.1416 = 4.1312 in.; length = 175 × 12 = 2,100 in.; heating surface =

$4.1312 \times 2{,}100 = 8{,}675.52$ sq. in. $= 60.247$ sq. ft.; adding allowance for elbows and manifolds, $60.247 + 2.25 = 62.5$ sq. ft., nearly. Ans.

(*b*) $175 \div 25 = 7$ rows. Ans.

(*c*) Heating surface $= 5.215 \times 2{,}100 = 10{,}951.5$ sq. in. $= 76.05$ sq. ft.; $76.05 + 2.25 + .75 = 79.05$ sq. ft. Ans.

(242) In the formula $\frac{4h^2}{3}\sqrt{\frac{D}{h} - .608}$, $h =$ the height of the segment $= 5$ in., and $D =$ the diameter of the circle $= 56$ in. Hence, the area of the segment $=$ $\frac{4 \times 5^2}{3}\sqrt{\frac{56}{5} - .608} = \frac{100}{3}\sqrt{10.592} = 33\frac{1}{3} \times 3.255 = 108.5$ sq. in. Ans.

(243) In Fig. 7, let $ACBD$ represent a section of the largest square bar that can be planed from the round bar. AB and CD each $= 2$ in., and in the right-angled triangle AOC, the sides AO and CO each $= 1$ in. Hence, the hypotenuse $AC = \sqrt{1^2 + 1^2} = \sqrt{2} = 1.4142$ in. Ans. Hence, the largest square bar that can be planed from the round bar is 1.4142″ square.

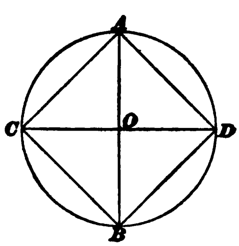

FIG. 7.

(244) The area of a circle 15 in. in diameter $= 15^2 \times .7854 = 176.715$ sq. in. Hence, the area of a sector of this circle whose angle is $12\frac{1}{2}° = 176.715 \times \frac{12\frac{1}{2}}{360} = \frac{2{,}208.937}{360} = 6.1359$ sq. in. Ans.

(245) (*a*) The side of a square whose area $= 103.8691$ sq. in. $= \sqrt{103.8691} = 10.1916$ in. Ans.

(*b*) The diameter of a circle having the same area $=$ $\sqrt{\frac{103.8691}{.7854}} = 11\frac{1}{2}$ in. Ans

(*c*) Perimeter of the square $= 10.1916 \times 4 = 40.7664$ in.; circumference of the circle $= 11.5 \times 3.1416 = 36.1284$ in.; difference $= 40.7664 - 36.1284 = 4.638$ in. Ans.

(246) With 5 in. allowed for lap, the length of the plate which forms the shell is $46 - 5 = 41$ in. This is the length of the circumference of the shell. Hence, the diameter corresponding to this circumference is $\frac{41}{3.1416} = 13.05$ in. Ans.

(247) The convex area is the area of the outside surface, not including the area of the ends. The circumference of the base $= 26 \times 3.1416 = 81.6816$ in. This reduced to feet, since the area is to be in feet, $= 81.6816 \div 12 = 6.8068$. Convex area $= 6.8068 \times 10\frac{1}{2} = 71.4714$ sq. ft. Ans.

(248) The perimeter of the base $= 4 \times 6 = 24$ in. $= 2$ ft. Convex area $= 2 \times 12 = 24$ sq. ft. The area of the bases is found as follows: In Fig. 8, $AB = 4$ in. and $AC = 2$ in.; since this is a regular hexagon, $AO = AB = 4$ in. OC, therefore, $= \sqrt{4^2 - 2^2} = \sqrt{12} = 3.4641$ in.; area of triangle $AOB = \frac{4 \times 3.4641}{2} = 6.9282$ sq. in.; area of base $= 6.9282 \times 6 = 41.5692$, and the area of both bases $= 41.5692 \times 2 = 83.1384$ sq. in. This reduced to square feet $= \frac{83.1384}{144} = .5774$. Hence, the area of the entire surface of the column is $24 + .5774 = 24.5774$ sq. ft. Ans.

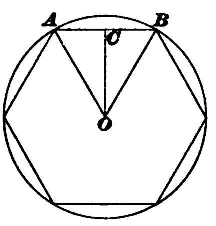

FIG. 8.

(249) The cubical contents in cubic inches = area of base in square inches $\times$ altitude in inches. The area of the base in the last example was found to be 41.5692 sq. in.; altitude $= 12 \times 12 = 144$ in. Hence, the cubical contents $= 41.5692 \times 144 = 5{,}985.9648$ cu. in. Ans

(250) This example is solved by combining the rules for the circular ring (see Art. **406**) and for the cylinder. To obtain the area of one end of the tube we have $4^2 \times .7854 = 12.5664$ = area of a circle 4 inches in diameter; $3.73^2 \times .7854 = 10.9272$ = area of a circle 3.73 inches in diameter; difference $= 12.5664 - 10.9272 = 1.6392$ = area of one end of the tube. The cubical contents $= 1.6392 \times$

$12 = 19.6704$ cu. in.; the weight $= 19.6704 \times .28 = 5.5$, or $5\frac{1}{2}$ lb. Ans.

(251) This example is done exactly like the one given in Art. **417**, and the solution is given here without explanation.

(*a*) In the formula $\frac{4h^2}{3}\sqrt{\frac{D}{h} - .608}$, h in this case $= 18$, and $D = 60$.

Substituting, area $=$

$$\frac{4 \times 18^2}{3}\sqrt{\frac{60}{18} - .608} = \frac{4 \times 324}{3}\sqrt{3.333 - .608} = 432 \times$$

$\sqrt{2.725} = 432 \times 1.65 = 712.8$ sq. in. This reduced to square feet $= 712.8 \div 144 = 4.95$. Hence, the steam space $= 4.95 \times 16 = 79.2$ cu. ft. Ans.

(*b*) Total area of one end of boiler in square inches $= 60^2 \times .7854 = 2,827.44$. From this is to be subtracted the area of the tube ends and of the segment found above.

Area of ends of tubes	$= 3.5^2 \times .7854 \times 64 =$	615.75 sq. in.
Area of segment	$=$	712.8 sq. in.
		1,328.55 sq. in.

Area of water space $= 2,827.44 - 1,328.55 = 1,498.89$ sq. in.

Contents of water space $= 1,498.89 \times 16 \times 12 = 287,786.88$ cu. in., and $287,786.88 \div 231 = 1,245.83$, number of gallons, or say 1,246 gal. Ans.

(252) Contents of pump cylinder $=$ area of piston $\times$ length of stroke $= 4^2 \times .7854 \times 10 = 125.664$ cu. in. Contents of square tank $= 6 \times 5 \times 3 = 90$ cu. ft. $= 90 \times 1,728$, or 155,520 cu in. Contents of round tank $= 9^2 \times .7854 \times 10 \times 1,728 = 1,099,308$ 672 cu. in.

(*a*) Contents of both tanks $= 155,520 + 1,099,308.672 = 1,254,828.672$ cu. in. This divided by $125.664 = 9,985.585$, the number of strokes of the pump required to fill the tanks. Since the pump makes 120 strokes per minute, the number of minutes required $= 9,985.585 \div 120 = 83.213 =$ 1 hr. 23.213 min. Ans.

(*b*) With a loss of 10%, the pump would deliver only 90% of 125.664 cu. in. at each stroke, or $125.664 \times .90 = 113.0976$ cu. in. Therefore, the number of strokes $= 1{,}099{,}308.672 \div 113.0976 = 9{,}720$; $9{,}720 \div 120 = 81$ min. $= 1$ hr. 21 min. Ans.

(*c*) $75 \times 30 \times 12 = 27{,}000$ in. passed through by the piston in half an hour. The problem is now, in effect, to find what size of piston would deliver 155,520 cu. in. of water in one stroke 27,000 in. long. In other words, knowing the volume and altitude of a cylinder, we have to obtain the area of the base. Hence, area of piston $= 155{,}520 \div 27{,}000 = 5.76$ sq. in. Diameter of piston $= \sqrt{5.76 \div .7854} = 2\frac{11}{16}$ in., nearly. Ans.

(253) Let the equilateral triangle $A\ B\ C$ (Fig. 9) represent the base of the pyramid. The altitude $A\ D$ of the triangle is evidently equal to $\sqrt{10^2 - 5^2} = \sqrt{75} = 8.6602$ in., and its area $= \dfrac{10 \times 8.6602}{2} = 43.301$ sq. in. The volume of the pyramid = area of base $\times \frac{1}{3}$ altitude $= \dfrac{43.301 \times 10}{3} = 144.336$ cu. in. Ans.

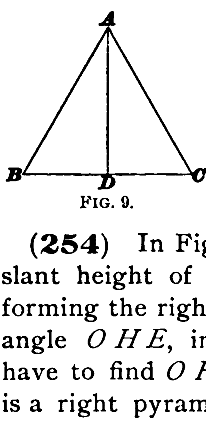

FIG. 9.

(254) In Fig. 10, let $O\ H$ be the altitude and $O\ E$ the slant height of the pyramid. Connect points H and E, forming the right-angled triangle $O\ H\ E$, in which we have to find $O\ H$. Since it is a right pyramid, point H will fall at the center of the base $A\ B\ C\ D$, and, hence, the line $H\ E = \frac{1}{2}\ A\ B$, or 8 in.; $O\ E = 25$ in.; therefore, $O\ H = \sqrt{25^2 - 8^2} = \sqrt{561} = 23.6854$ in. Ans

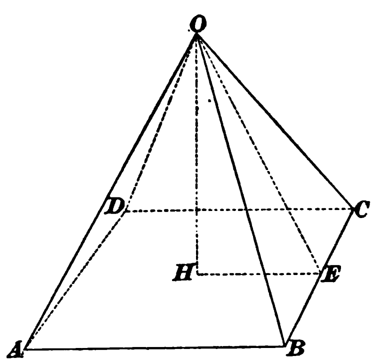

FIG. 10.

(255) The area of the convex surface = circumference of base $\times \frac{1}{2}$ slant height =

$18.8496 \times \frac{10}{2} = 94.248$ sq. in. The area of the entire surface $= 94.248$ sq. in. + the area of the base. The diameter of the base $= \frac{18.8496}{3.1416} = 6$ in.; hence, the area of the base $= 6^2 \times .7854 = 28.2744$; therefore, the area of the entire surface $= 94.248 + 28.2744 = 122.5224$ sq. in. Ans.

(256) The volume = area of base $\times \frac{1}{3}$ altitude $= 28.2744 \times \frac{9}{3} = 84.8232$ cu. in. Ans.

(257) Circumference of the base $= 16 \times 3.1416 = 50.2656$ in. Radius of base $= 16 \div 2 = 8$ in.; slant height $= \sqrt{8^2 + 6^2} = \sqrt{100} = 10$ in.; area of convex surface $= \frac{50.2656 \times 10}{2} = 251.328$ sq. in. Ans.

(258) The vat has the form of an inverted frustum of a pyramid. Area of larger base $= 15^2 = 225$ sq. ft.; area of smaller base $= 12^2 = 144$ sq. ft. Hence, from the rule for the volume of the frustum of a pyramid, the contents of the vat in cubic feet $= (225 + 144 + \sqrt{225 \times 144})\frac{11}{3} = (369 + 180) \times \frac{11}{3} = 549 \times \frac{11}{3} = 2{,}013$ cu. ft. This should be reduced to cubic inches by multiplying by 1,728, the number of cubic inches in a cubic foot. $2{,}013 \times 1{,}728 = 3{,}478{,}464$ cu. in. Since there are 231 cubic inches in a gallon, the number of gallons that the vat will hold $= \frac{3{,}478{,}464}{231} = 15{,}058.29$. Ans.

(259) The pail is in the form of a frustum of a cone. Area of larger base $= 12^2 \times .7854 = 113.0976$ sq. in. Area of smaller base $= 63.6174$ sq. in. Hence, the contents in cubic inches =

$$(113.0976 + 63.6174 + \sqrt{113.0976 \times 63.6174}) \times \frac{11}{3} =$$

$$(176.715 + \sqrt{7{,}194.9753})\frac{11}{3} = (176.715 + 84.8232) \times \frac{11}{3} =$$

$$261.5382 \times \frac{11}{3} = 958.9734.$$

The contents of the vat in cubic inches were found in the last example to be 3,478,464. Hence, the number of pails of water required to fill the vat $= 3,478,464 \div 958.9734 = 3,627.28$. Ans.

(260) The area of the convex surface = half the sum of the perimeters of the upper and lower bases $\times$ the slant height, or $\frac{48 + 36}{2} \times 32 = 42 \times 32 = 1,344$ sq. in.

(261) See note following this question.

Outside diameter of upper base $= \frac{170.5}{3.1416} =$ about 54.27 in.; inside diameter $= 54.27 - 2.5 = 51.77$ in.; area of upper base $= 51.77^2 \times .7854 = 2,105$ sq. in., nearly.

Outside diameter of lower base $= \frac{190}{3.1416} = 60.48$ in., nearly; inside diameter $= 60.48 - 2.5 = 57.98$ in.; area of lower base $= 57.98^2 \times .7854 = 2,640$ sq. in., nearly.

Contents of the tank in cubic inches $= (2,105 + 2,640 + \sqrt{2,105 \times 2,640}) \times \frac{7 \times 12}{3} = (4,745 + 2,357) \times 28 = 7,102 \times 28 = 198,856$ cu. in. Hence, the number of gallons $= 198,856 \div 231 = 860.8$. Therefore, in round numbers, the tank will hold 861 gallons. Ans.

(262) (*a*) The area of the surface equals the square of the diameter $\times$ $3.1416 = 22.5^2 \times 3.1416 = 506.25 \times 3.1416 = 1,590.435$ sq. in. Ans.

(*b*) The cubical contents = the cube of the diameter $\times$ $.5236 = 11,390.625 \times .5236 = 5,964.1313$ cu. in. Ans.

(263) Having given the area of the surface, to find the volume we must first obtain the diameter. The process is just the reverse of finding the surface when the diameter is given. Hence, the diameter $= \sqrt{201.0624 \div 3.1416} = \sqrt{64} = 8$ in. The volume $= 8^3 \times .5236 = 268.0832$ cu. in. Ans.

(264) (*a*) Volume $= 8^3 \times .5236 = 512 \times .5236 =$ 268.0832 cu. in.

(*b*) Submerging the ball would have the same effect as increasing the quantity of water in the vessel by 268.0832 cu. in. The area of the bottom of the vessel $= 10 \times 12 =$ 120 sq. in. The added water would, therefore, take the shape of a prism having a base of 120 sq. in., a volume of 268.0832 cu. in., and whose altitude is unknown. Dividing the volume by the area of the base will give the altitude, or the rise of the water. $268.0832 \div 120 = 2.234$ in. Ans.

(*c*) To obtain the volume of a ball, we cube the diameter and multiply by .5236. To find the diameter from the volume, the process is just the reverse, viz., *divide* by .5236 and *extract the cube root* of the result. $179.5948 \div .5236 =$ 343; $\sqrt[3]{343} = 7$ in. Ans.

(265) One-half the volume of the ball, which is equal to the quantity of water required to half fill the ball, is $\frac{10^3 \times .5236}{2} = 261.8$ cu. in. Weight $= 261.8 \times .03517 +$ $2\frac{1}{2} = 9.2 + 2.5 = 11.7$ lb., or 12 lb., nearly. Ans.

(266) The bottom of the kettle has the shape of half a ball whose diameter is 24 in. The depth of the hemispherical part is equal to half the diameter, or 12 in., and the water extends up into the cylindrical part of the kettle, a distance of $16 - 12$, or 4 in. Hence, we have to find, first, the volume of half a ball 24 in. in diameter, and, second, the volume of a cylinder 24 in. in diameter and 4 in. high.

Volume of the half ball $= \frac{24^3 \times .5236}{2} = 3{,}619.1232$ cu. in.

Volume of cylinder $= 24^2 \times .7854 \times 4 = 1{,}809.5616$ cu. in.

Total volume of water is the sum of these two volumes, or 5,428.6848 cu. in. This, divided by 231, the number of cubic inches in a gallon, gives 23.5 gal. as the capacity. Ans.

(267) (*a*) Given $OB = \frac{16}{2}$, or 8 inches, and $OA = \frac{13}{2}$, or $6\frac{1}{2}$ inches (Fig. 11), to find the volume, area, and weight:

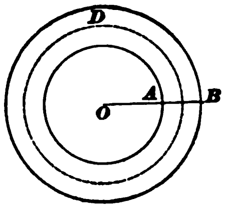

FIG. 11.

Radius of center circle equals $\frac{8+6.5}{2}$, or $7\frac{1}{4}$ inches. Length of center line $= 2 \times 3.1416 \times 7\frac{1}{4} = 45.5532$ inches.

The radius of the inner circle is $6\frac{1}{2}$ inches, and of the outer circle 8 inches; therefore, the diameter of the cross-section on the line AB is $1\frac{1}{2}$ inches. Then, the area of the ring is $1\frac{1}{2} \times 3.1416 \times 45.553 = 214.665$ square inches. Ans.

Diameter of cross-section of ring $= 1\frac{1}{2}$ inches.

Area of cross-section of ring $= (1\frac{1}{2})^2 \times .7854 = 1.76715$ sq. in. Ans.

Volume of ring $= 1.76715 \times 45.553 = 80.499$ cu. in. Ans.

(*b*) Weight of ring $= 80.499 \times .261 = 21$ lb. Ans.

MECHANICS.

(QUESTIONS 268–317.)

(268) See Arts. **438** to **440.**

(269) See Art. **442.**

(270) See Art. **464.**

(271) See Art. **469.**

(272) See Art. **473.**

(273) See Art. **478.**

(274) Using rule, Art. **486,**
$75 \times$ power arm $= 975 \times 4$, or power arm $= \frac{975 \times 4}{75} =$ 52 in. = 4 ft. 4 in. Ans.

(275) Using rule, Art. **486,**

$$\text{power} \times 15 = 57 \times 4, \text{ or power} = \frac{57 \times 4}{15} = 15.2 \text{ lb.} \quad \text{Ans.}$$

(276) (*a*) Weight of the sheet lead $= 25 \times 6 \times 6 = 900$ lb. Hence, using rule, Art. **486,** and remembering that the length of crank to which the handle is attached is only one-half of the diameter of the circle described by the handle, we have

$$\text{power} \times (12 \times 2) = 900 \times 5, \text{ or power} = \frac{900 \times 5}{12 \times 2} = 187.5 \text{ lb.}$$
Ans.

(*b*) During one turn of the handle the power moves through $12 \times 2 \times 3.1416$ inches, and the weight moves through 5×3.1416 inches. The velocity ratio $= (12 \times 2 \times 3.1416) \div (5 \times 3.1416) = \frac{24}{5}$. Then, $10 \times \frac{24}{5} = 48$ ft. = distance that handle travels in raising the roll 10 ft. Ans.

(**277**) (*a*) Since there are two movable blocks, there are four parts to the rope. Hence, the velocity ratio is 4, and according to the statement in the text (calling P the power), $P \times 4 = 500$, or $P = \frac{500}{4} = 125$ lb. Ans.

(*b*) With three movable pulleys, the velocity ratio is 6. Hence, $W = P \times$ velocity ratio $= 125 \times 6 = 750$ lb. Ans.

(**278**) (*a*) See Art. **507.**

(*b*) See law **6**, Art. **509.**

(**279**) The cube of lead. (See law **7**, Art. **509.**)

(**280**) See Arts. **524** and **525.**

(**281**) Total height of lift $= 125 + 75 = 200$ ft. Weight of water $= 10{,}200 \times 8.355$. Work done per minute $= \frac{10{,}200 \times 8.355 \times 200}{10}$ ft.-lb. Therefore, horsepower $= \frac{10{,}200 \times 8.355 \times 200}{10 \times 33{,}000} = 51.65$ H. P., nearly. Ans.

(**282**) See Art. **521.**

(**283**) The pressure exerted in every direction by a liquid when at rest.

(**284**) (*a*) Area of bottom $= 5 \times 5 = 25$ sq. ft. $= 25 \times 144 = 3{,}600$ sq. in. Then, by rule, Art. **541** and the note in Art. **549**, total pressure upon the bottom $= 3{,}600 \times 5 \times .434 = 7{,}812$ lb. Ans.

(*b*) $5 \times \frac{2}{3} = \frac{10}{3}$. Pressure per square inch on bottom when tank is two-thirds full $= .434 \times \frac{10}{3} = 1.447$ lb. per sq. in. Ans.

(**285**) (*a*) Areas of bottoms of both vessels are $12^2 \times .7854$ sq. in. By rule, Art. **541**, the pressure on their bottoms $= 12^2 \times .7854 \times .434 \times 2 = 98.2$ lb., nearly. Ans.

(*b*) For vessel *a*, the weight of the water contained in it = pressure on the bottom = 98.2 lb. Ans.

For vessel b, the weight of the water contained in it $= 2^2 \times .7854 \times 14 \times .03617 + 12^2 \times .7854 \times 10 \times .03617 = 42.5$ lb. Ans.

(c) Area of surface $c = 12^2 \times .7854 - 2^2 \times .7854 = 109.956$ sq. in. Then, by rule, Art. **544,** $109.956 \times .434 \times \frac{14}{12} = 55.7$ lb. Ans.

(286) (a) $80 - 10 = 70$ ft. = head. Hence, $.434 \times 70 = 30.38$ lb. per sq. in.

(b) Force = pressure $= 4.5^2 \times .7854 \times .434 \times 80 = 552.2$ lb. Ans.

(287) See Art. **548.**

(288) (a) Pressure per square inch on $a = 1^2 \div .7854 \times 10 = \frac{10}{.7854}$ lb. $20^2 \times .7854 \times \frac{10}{.7854} = 4{,}000$ lb. Ans.

(b) Velocity ratio $= \frac{4{,}000}{10} = 400$. Then, distance b moves $= \frac{10''}{400} = .025''$. Ans.

(289) (a) Three tons $= 2{,}000 \times 3 = 6{,}000$ lb. Area of piston $= 9^2 \times .7854 = 63.6174$ sq. in. $\frac{6{,}000}{63.6174} = 94.3$ lb. per sq. in., nearly. Ans.

(b) $9^2 \times .7854 \times 10 \times 12 = 7{,}634$ cu. in. $= 7{,}634 \div 231 = 33$ gal., nearly. Ans.

(290) (a) See Art. **554.**

(b) $16 \times \frac{3}{4} = 12$ ft. Hence, $.434 \times 12 = 5.21$ lb. per sq. in. Ans.

(291) Total pressure tending to separate end from shell $= 30^2 \times .7854 \times 80 = 56{,}548.8$ lb. Circumference of shell $= 30 \times 3.1416 = 94.248''$. Number of rivets $= 94.248 \div 2 = 47$, nearly. Therefore, $56{,}548.8 \div 47 = 1{,}203.17$ lb. = force tending to tear off each rivet. Ans.

(292) See Art. **561.**

(293) For the first part of the question, see explanation to Fig. 107, Art. **561.** For the second part of the question, take into consideration the fact that the specific gravity of melted lead is greater than that of iron.

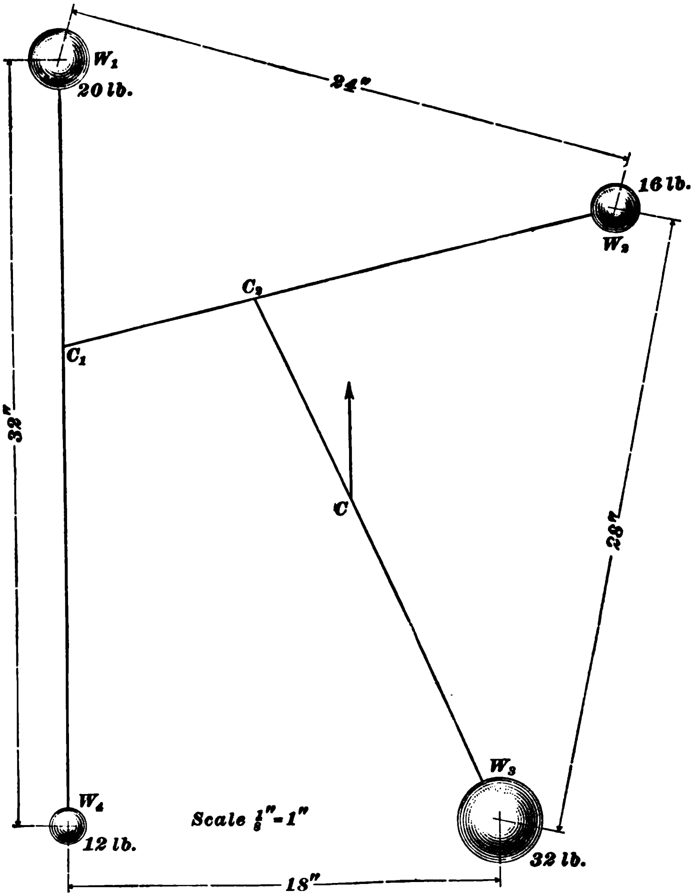

FIG. 12.

(294) The required force equals the weight of a volume of water equal to that of the cube less the weight of the cube. Hence, force $= 6 \times 6 \times 6 \times .03617 - 3 = 4.81$ lb. Ans.

(295) See Art. **564.**

(296) Distance passed over in one hour $= 6 \times 3.1416 \times 220 \times 60$ ft. $= \dfrac{6 \times 3.1416 \times 220 \times 60}{5,280} = 47.124$ mi. per hr. Ans.

(297) See Art. **477.**

(298) It is first necessary to make an accurate sketch of the positions of the different weights, as here shown in Fig. 12; the larger the drawing, the better will be the results. Find the position of the center of gravity of the weights W_1 and W_4 by applying rule, Art. **478,** thus, distance of center of gravity from $W_1 = \dfrac{12 \times 32}{12 + 20} = 12''$. Scale off $12''$, thus locating C_1. Join C_1 and W_2, measure the distance $C_1 W_2$, and again apply the rule. $C_1 W_2 = 24\frac{3}{4}''$. Hence, distance of center of gravity of W_1, W_4, and W_2 from C_1 measured on $C_1 W_2 = \dfrac{16 \times 24.75}{12 + 20 + 16} = 8\frac{1}{4}''$. Lay off $C_1 C_2 = 8\frac{1}{4}''$, and join C_2 and W_3. Measuring $C_2 W_3$, it is found to equal $24.72''$. The weight concentrated at C_2 is $12 + 20 + 16 = 48$ lb. Distance of center of gravity of all four weights from C_2 measured on line $C_2 W_3$ is $\dfrac{32 \times 24.72}{32 + 48} = 9.9''$, nearly. Locate C $9.9''$ from C_2 on line $C_2 W_3$, and it is the center of gravity of all the weights. The distance of C from the line $W_1 W_4$ measures $11.92''$. Ans.

(299) Make an accurate sketch of the triangle, as here shown in Fig. 13, and find the center of gravity by means of rule, Art. **481.** The distance of the center of gravity from $A\,C = 1\frac{3}{32}''$. Ans.

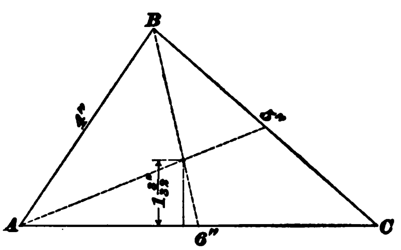

FIG. 13.

(300) This being an experimental problem, no solution can be given.

(301) The force required equals that required to overcome the friction, or $1,720 \times .21 = 361.2$ lb. Ans.

(302) The efficiency being 41%, only .41 of the force applied at P can be utilized in raising the load. Therefore, by rule, Art. **504,** $.41\ P = \dfrac{6{,}780 \times \frac{1}{3}}{6.2832 \times 9}$; whence, $P = \dfrac{2{,}260}{.41 \times 6.2832 \times 9} = 97.5$ lb., nearly. Ans.

(303) (*a*) Using rule, Art. **504,**

$P \times 3.1416 \times 9 \times 2 = 6{,}780 \times \dfrac{1}{3} = 2{,}260$, or $P = \dfrac{2{,}260}{3.1416 \times 9 \times 2} =$ 40 lb., nearly. Ans.

(*b*) Distance that power moves in one revolution of $FP = 3.1416 \times 9 \times 2 = 56.5488''$; distance that weight moves $= \frac{1}{3}''$. Hence, by definition in Art. **506,** velocity ratio $= 56.5488 \div \dfrac{1}{3} = 169.6$, nearly. Ans.

The same result may be obtained more easily by simply dividing the weight lifted by the theoretical power required to lift the weight; thus, $\dfrac{6{,}780}{40} = 169.5$. Ans.

(304) Volume of ball $= .5236 \times 4^3$ cu. in. Weight of 1 cu. in. of lead is .411 lb. (See table of Specific Gravities and Weights per cubic foot.) Hence, weight of ball $= .5236 \times 4^3 \times .411 = 13.77$ lb. Applying rule, Art. **518,**

centrifugal force $= .00034 \times 13.77 \times \dfrac{36 \div 2}{12} \times 96^2 = 64.72$ lb. Ans.

(305) Volume $= (6^2 \times .7854 - 5^2 \times .7854) \times 12 = 103.67$ cu. in. From the table just mentioned, 1 cu. in. of copper weighs .318 lb. Weight of cylinder $= 103.67 \times .318 = 32.97$ lb. Weight of equal volume of water $= 103.67 \times .03617 = 3.75$ lb. Then, $32.97 - 3.75 = 29.22$ lb. Ans.

(306) Force required to overcome the friction $= 11{,}426 \times .08 = 914.08$ lb. Space passed through in one minute $= 580$ ft. Hence, foot-pounds of work per minute $= 914.08 \times 580$, and horsepower $= \dfrac{914.08 \times 580}{33{,}000} = 16.07$ H. P. Ans.

(307) See Arts. **529** to **531.**

(308) Work done $= 120 \times 15 = 1{,}800$ ft.-lb. Ans.

It makes no difference, theoretically, in regard to the total number of foot-pounds of work done what kind of a machine is used to do the work, since the power multiplied by the distance through which it moves equals the weight multiplied by the distance through which it moves.

(309) A mile per minute $= \frac{5{,}280}{60} = 88$ ft. per sec. Hence, applying rule, Art. **529,** kinetic energy $= \frac{400 \times 88^2}{64.32} =$ 48,159.2 ft.-lb. per sec. Ans.

(310) See Art. **532.**

(311) Cubic contents of 1,000 bricks $= 8 \times 4 \times 2 \times 1{,}000$ cu. in. $= \frac{8 \times 4 \times 2 \times 1{,}000}{1{,}728}$ cu. ft. Brick weighs 118 lb. per cu. ft. (see table of Specific Gravities and Weights per cubic foot of Miscellaneous Substances). Hence, the weight of the bricks $= \frac{8 \times 4 \times 2 \times 1{,}000}{1{,}728} \times 118 = 4{,}370$ lb., nearly. Ans.

(312) 1 cu. yd. $= 27$ cu. ft. Weight of 1 cubic foot of sand is, from the table referred to in Example 311, 113 lb. Hence, weight of 1 cu. yd. $= 27 \times 113 = 3{,}051$ lb. Ans.

(313) (*b*) Since there are 3 fixed and 3 movable pulleys, there are 6 parts to the rope, and the power must move through 6 times the distance that the weight moves. Consequently, the velocity ratio is 6. Ans.

(*a*) The weight lifted $= .82 \times 100 \times 6 = 492$ lb. Ans.

(314) (*a*) Applying rule, Art. **486,** to Fig. 71,

$$28 \times (43 - 5\tfrac{1}{4}) = W \times 5\tfrac{1}{4}, \text{ or } W = \frac{28 \times 37.75}{5.25} = 201\tfrac{1}{3} \text{ lb. Ans.}$$

Apply same rule to Fig. 72.

$$28 \times 43 = W \times 5\tfrac{1}{4}, \text{ or } W = \frac{28 \times 43}{5.25} = 229\tfrac{1}{3} \text{ lb. Ans.}$$

(b) Because the power arm is longer in the second case and the weight arm is the same in both cases.

(315) Applying rule, Art. **493**,

$$P \times .85 \times 21 \times 70 \times 96 = 900 \times 14 \times 20 \times 6,$$

or $$P = \frac{900 \times 14 \times 20 \times 6}{.85 \times 21 \times 70 \times 96} = 12.61 \text{ lb.} \quad \text{Ans.}$$

(316) Length of $a\,b = \sqrt{108^2 + 18^2} = 109.5$ ft. Consequently, by rule **I**, Art. **501**,

$$P = \frac{275 \times 18}{109.5} = 45.21 \text{ lb.} \quad \text{Ans.}$$

(317) Volume of ball $= .5236 \times 6^3 = 113.1$ cu. in.

Weight of ball $= 113.1 \times .261 = 29.52$ lb.

Weight of equal volume of mercury $= 113.1 \times .492 = 55.65$ lb.

Therefore, pressure required to keep the ball beneath the surface $= 55.65 - 29.52 = 26.13$ lb. Ans.

The depth has nothing to do with the case.

MECHANICS.

(QUESTIONS 318–386.)

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(318) (*a*) Because there is less friction at the center than at the sides.

(*b*) See Art. **569.**

(319) Using rule, Art. **573,**

$$Q = .0408 \times \left(1\frac{1}{4}\right)^2 \times 8 = .51 \text{ gal. per sec.} =$$
$$.51 \times 60 = 30.6 \text{ gal. per min.}$$

Number of gallons which tank will hold $= 8 \times 6 \times 3 \times 7.48 = 1{,}077.12$ gal.

Time required to fill the tank $= 1{,}077.12 \div 30.6 = 35.2$ min. Ans.

(320) See Art. **567.**

(321) See Art. **568.**

(322) (*a*) In the 2-inch pipe, because the larger the pipe, the less are the losses due to friction, etc.

(*b*) For the $\frac{1}{2}$-inch pipe, rule, Art. **571,** may be used, since the length of the pipe exceeds 10,000 times its diameter, therefore,

$$v_m = 2.315\sqrt{\frac{50 \times .5}{.025 \times 500}} = 2.315 \times 1.4142 = 3.274 \text{ ft. per sec.}$$

Ans.

For the 2-inch pipe, use rule, Art. **570.**

$$v_m = 2.315\sqrt{\frac{50 \times 2}{.025 \times 500 + .125 \times 2}} = 2.315 \times 2.8006 =$$
$$6.483 \text{ ft. per sec. Ans.}$$

(323) Using rule, Art. **571**, in accordance with the directions given in Art. **575**,

$$v_m = 2.315\sqrt{\frac{190 \times .75}{.025 \times 300}} = 10.1 \text{ ft. per sec.}$$

From the table $f = .0205$ for $v_m = 8$ and $.0193$ for $v_m = 12$. $.0205 - .0193 = .0012$ = difference in the values of f for a difference in the v_ms of $12 - 8 = 4$ ft. per sec. $10.1 - 8 = 2.1$. Hence, $4 : 2.1 :: .0012 : x$, or $x = .00063 = .0006$ when using but four decimal places. Hence, $v_m = .0205 - .0006 = .0199$. Now, using rule, Art. **575**,

$$Q = .09445 \times \left(\frac{3}{4}\right)^2 \sqrt{\frac{190 \times .75}{.0199 \times 300 + .125 \times .75}} =$$

.2574 gal. per sec = $.2574 \times 60 = 15.44$ gal. per min. Ans.

(324) See Art. **581.**

(325) See Art. **584.**

(326) See Arts. **584** and **581.**

(327) See Arts. **582, 583,** and **588.**

(328) The volume of a gas may be changed by increasing or decreasing the pressure. The student should give his own illustration.

(329) Original pressure = 14.7 lb. per sq. in. Take the original volume as say 1 cu. ft. Then, the final volume is $\frac{1}{3}$ cu. ft., and the final pressure is found, by applying rule, Art. **591**, to be

$$p_1 = (14.7 \times 1) \div \frac{1}{3} = 44.1 \text{ lb. per sq. in. Ans.}$$

(330) (*a*) Applying rule, Art. **592**,

$$v_1 = \frac{14.7 \times 1{,}000}{80} = 183.75 \text{ cu. in. Ans.}$$

(*b*) Again applying rule, Art. **592**,

$$v_1 = \frac{14.7 \times 1{,}000}{200} = 73.5 \text{ cu. in., nearly. Ans.}$$

(331) See Art. **593.**

(332) See Art. **594.**

(333) See Art. **597.**

(334) Total pressure on under side of piston $= 10^2 \times .7854 \times 14.7 = 1{,}154.54$ lb. Force required to pull piston out of cylinder $1{,}154.54 - 30 = 1{,}124.54$ lb. Ans.

(335) The air contained in the globe C can then escape, and the water will then simply flow into C until its level reaches the hole, after which it will escape through the hole.

(336) See Art. **608.**

(337) See Art. **609.**

(338) (*a*) During suction, part of the water in the pipe P will flow back into the pump barrel; during discharge, part of the water in the pump barrel will flow back into the suction pipe.

(*b*) In order to drive out the air in the suction pipe.

(339) See Art. **612.**

(340) See Art. **612.**

(341) See Art. **614.**

(342) Yes; it is the casting from which pipe d leads.

(343) See Art. **615.**

(344) Applying rule, Art. **619,** to find the probable discharge in gallons per minute,

$$G = .03264 \times 4^2 \times \left(\frac{9 \times 120}{12}\right) = 47 \text{ gal. per min.}$$

Then, applying rule, Art. **620,**

$$H = .00038 \times 47 \times 100 = 1.786 \text{ H. P.} \quad \text{Ans.}$$

(345) See Art. **626.**

(346) (*a*) From Table 17, Art. **626,**

$$W = \left(\frac{3}{8}\right)^2 \times .7854 \times 50{,}000 = 5{,}522 \text{ lb.} \quad \text{Ans.}$$

(*b*) From Table 17, Art. **626,** the safe steady load may be taken as

$$W = \left(\frac{3}{8}\right)^2 \times .7854 \times 12{,}000 = 1{,}328 \text{ lb. Ans.}$$

(347) Using rule **I,** Art. **651,** and table given in Art. **626,**

$$P = \frac{2 \times \frac{1}{8} \times 2{,}200}{2} = 275 \text{ lb. per sq. in.}$$

(348) Using rule **IV,** Art. **651,** and taking the pressure as $75 \times .434 = 32.55$ lb. per sq. in.,

$$S = \frac{14 \times 32.55}{2 \times \frac{1}{8}} = 1{,}823 \text{ lb. per sq. in., nearly. Ans.}$$

(349) Speed in feet per minute $= \frac{18 \times 60}{12} = 90.$

Applying rule, Art. **619,**

$$G = .03264 \times 7.5^2 \times 90 = 165.24 \text{ gal. per min. Ans.}$$

(350) Total height to which the water is raised $= 175 + 18 = 193$ ft.

Using rule, Art. **620,** $H = .00038 \times 150 \times 193 = 11$ H. P.

Using rule **II,** Art. **622,**

$$d = \sqrt{\frac{42{,}016.8 \times 11}{60 \times 120}} = 8'', \text{ nearly. Ans.}$$

Stroke $= 8 \times 1\frac{1}{2} = 12''$. Ans.

(351) $3^2 \times .7854 = 7.0686$ sq. in. $= \frac{7.0686}{144}$ sq. ft. $120 \div 7.48 = 16.043$ cu. ft. per min. $= \frac{16.043}{60}$ cu. ft. per sec.

$$\frac{16.043}{60} \div \frac{7.0686}{144} = \frac{16.043}{60} \times \frac{144}{7.0686} = 5.447 \text{ ft. per sec. Ans.}$$

(352) $39{,}600 \div (60 \times 60) = 11$ gal. per sec. $= \frac{11}{7.48}$ cu. ft. per sec.

$6^2 \times .7854 = 28.2744$ sq. in. $= \frac{28.2744}{144}$ sq. ft.

Then, $v_m = \frac{11}{7.48} \div \frac{28.2744}{144} = 7.49$ ft. per sec.

From the table given in Art. **575**, $f = .0214$ for $v_m = 6$ and $.0205$ for $v_m = 8$. Then, $.0214 - .0205 = .0009$; $8 - 6 = 2$, and $7.49 - 6 = 1.49$.

Hence, $2 : 1.49 :: .0009 : x$, or $x = .0007$ when using but four decimal places. Consequently, $f = .0214 - .0007 = .0207$.

Applying rule, Art. **572**,

$$h = \frac{.0207 \times 3{,}500 \times 7.49^2}{5.36 \times 6} + .0233 \times 7.49^2 = 127.7 \text{ ft. Ans.}$$

(353) Using rule **I**, Art. **651**,

$$P = \frac{2 \times \frac{3}{16} \times 8{,}000}{20} = 150 \text{ lb. per sq. in. Ans.}$$

(354) Using rule **II**, Art. **651**, and table given in Art. **626**,

$$D = \frac{2 \times \frac{1}{8} \times 400}{50} = 2''. \text{ Ans.}$$

(355) Applying rule **II**, Art. **629**,

$$12{,}000 \times (\tfrac{3}{8})^2 = 1{,}687.5 \text{ lb. Ans.}$$

(356) Apply rule **III**, Art. **633.**

$$\text{Load} = 1{,}000 \times (5\tfrac{1}{4})^2 = 27{,}562.5 \text{ lb. Ans.}$$

(357) Applying rule, Art. **649**,

$$\text{force} = 6^2 \times .7854 \times 60{,}000 = 1{,}696{,}464 \text{ lb. Ans.}$$

(358) See Arts. **585** and **586.**

(359) Apply rule **I**, Art. **630.**

$$\text{Safe load} = 100 \times 4^2 = 1{,}600 \text{ lb. Ans.}$$

(360) Area of cross-section $= 8^2 \times .7854 = 50.2656$ sq. in. 10 ft. $= 120'' = L$. Crushing strength $= 3.5$. (See Table 18, Art. **636.**) $a = 187.5$. (See Table 21, Art. **637.**) Substituting these values in the formula under rule, Art. **638**,

$$W = \frac{3.5 \times 50.2656}{\frac{120^2}{187.5 \times 8^2} + 1} = 80 \text{ tons, very nearly.}$$

Hence, $80 \div 6 = 13\frac{1}{3}$ tons = safe load. Ans.

(361) (See Art. **649.**) Area to be punched $= 1 \times 3.1416 \times \frac{7}{16} = 1.37445$ sq. in. Applying rule, Art. **649,**

$$\text{force} = 1.37445 \times 40{,}000 = 54{,}978 \text{ lb. Ans.}$$

(362) Applying rule, Art. **591,**

$$\text{new pressure} = \frac{42 \times 20\frac{1}{4}}{42 + 14} = 15.19 \text{ lb. per sq. in., nearly. Ans.}$$

(363) Area of cross-section $= (1\frac{1}{2})^2 \times .7854 = 1.7671$ sq. in.

Apply rule **I,** Art. **628.**

Safe steady load $= 12{,}000 \times 1.7671 = 21{,}205$ lb. Ans.

(364) Apply rule **I,** Art. **630.**

$$\text{Load} = 100 \times 6^2 = 3{,}600 \text{ lb. Ans.}$$

(365) Substituting, the values of $C = 40$, $S = 14^2 \times .7854 - 11.5^2 \times .7854 = 50.0693$, $L = 20 \times 12 = 240$, $a = 562.5$, and $d = 14$ in the formula given in connection with rule, Art. **638,** we have

$$W = \frac{40 \times 50.0693}{\frac{240^2}{562.5 \times 14^2} + 1} = \frac{2{,}002.772}{1.5225} = 1{,}315.45 \text{ tons.}$$

$$\frac{1{,}315.45}{6} = 219.24 \text{ tons. Ans.}$$

(366) (See Art. **649.**) Area punched $= 1\frac{1}{2} \times 3.1416 \times \frac{3}{4} = 3.5343$ sq. in. Force $= 3.5343 \times 60{,}000 = 212{,}058$ lb. Ans.

(367) Area of cross-section $= 1\frac{3}{4} \times 3 = 5.25$ sq. in.

Applying rule **I,** Art. **628,**

$$\text{safe load} = 5.25 \times 6{,}000 = 31{,}500 \text{ lb. Ans.}$$

(368) Apply rule **II**, Art. **630.**

Circumference $= .1\sqrt{W} = .1\sqrt{2,400} = 4.9''$. Ans.

(369) Apply rule, Art. **591.**

$$\text{Pressure} = \frac{1.11 \times 18}{.3} = 66.6 \text{ lb. per sq. in.} \quad \text{Ans.}$$

(370) Total pressure on the head $= 17^2 \times .7854 \times 160 = 36,317$; tension in each stud $= \frac{36,317}{16} = 2,270$ lb. say.

Applying rule **II**, Art. **628,**

cross-sectional area at bottom of thread $= \frac{2,270}{5,000} = .454$ sq. in.

This corresponds approximately to $\frac{7}{8}''$ studs; which would be the size used. Ans.

(371) Apply rule **II**, Art. **630.**

Circumference $= .1\sqrt{4,200} = 6.48''$, say $6\frac{1}{2}''$. Ans.

(372) Apply rule, Art. **592.**

$$\text{New volume} = \frac{45 \times 25}{15} = 75 \text{ cu. ft.}$$

Hence, $75 - 25 = 50$ cu. ft. = volume of second vessel. Ans.

(373) Apply rule **II**, Art. **628.**

$$\text{Area} = \frac{12,000}{4,000} = 3 \text{ sq. in.}$$

$$\text{Diameter} = \sqrt{\frac{3}{.7854}} = 1.95''+. \quad \text{Ans.}$$

(374) Apply rule **III**, Art. **633.**

Load $= 1,000 \times 4.75^2 = 22,562.5$ lb. Ans.

(375) First calculate the load it will sustain in the middle by means of rule, Art. **644.**

$$\text{Load in middle} = \frac{4 \times 10^2 \times 4 \times 30}{28} = 1,714\frac{2}{7} \text{ lb.}$$

Hence, the uniform load $= 1,714\frac{2}{7} \times 2 = 3,428\frac{4}{7}$ lb. Ans.

(376) Pressure in the condenser $= 30 - 20 = 10''$. Since a column of mercury $30''$ high produces a pressure of 14.7 lb. per sq. in., the pressure which a $10''$ column will produce is found by the proportion $30 : 10 :: 14.7 : x$. Hence, pressure in the condenser $= x = 4.9$ lb. per sq. in. Ans.

(377) Apply rule **II**, Art. **633.**

Circumference $= .0408 \sqrt{14,000} = 4.83''$, nearly. Ans.

(378) Apply rule, Art. **645.**

$$\text{Load} = \frac{4 \times 2^2 \times .6 \times 150}{6} = 480 \text{ lb. Ans.}$$

(379) Apply rule, Art. **591.**

$$\text{New pressure} = \frac{52 \times (300 - 120)}{300} = 31.2 \text{ lb. per sq. in. Ans.}$$

(380) (*a*) $12''$. Ans.

(*b*) $18''$. Ans.

(381) See Arts. **623** and **624.**

(382) Apply rule **I**, Art. **629.**

$$\text{Load} = 18,000 \times (\tfrac{13}{16})^2 = 11,883 \text{ lb. Ans.}$$

(383) Apply rule, Art. **644,** and multiply the result by 2.

$$\text{Load} = \frac{4 \times 6^2 \times 2 \times 160}{20} \times 2 = 4,608 \text{ lb. Ans.}$$

(384) Apply rule **II**, Art. **629.**

$$\text{Load} = 12,000 \times (\tfrac{5}{8})^2 = 4,687.5 \text{ lb. Ans.}$$

(385) Apply rule **I**, Art. **633.**

$$\text{Load} = 600 \times 6^2 = 21,600 \text{ lb. Ans.}$$

(386) 4 ft. $= 48''$. Area to be sheared $= 48 \times \frac{1}{2} =$ 24 sq. in. Applying rule, Art. **649,**

$$\text{force} = 24 \times 40,000 = 960,000 \text{ lb. Ans.}$$

PLUMBING AND DRAINAGE.

(QUESTIONS 387-486.)

(387) (*a*) (See Art. **685.**) Portland cement and clean, sharp sand mixed in equal proportions into a thick mortar. The spigot and socket should be wetted before the cement is applied. The surface of the joint should be finished smooth,

(*b*) (See Art. **684.**) Plaster of Paris. Mix thin with water. Use in small quantities. Use no oil cement for this work. Wet the surfaces to be joined and apply the plaster quickly.

(*c*) (See Arts. **687** to **689.**) Use either glaziers' putty, red lead, or white lead. Surfaces must be perfectly dry.

(*d*) (See Art. **688.**) Use red lead worked into a putty with linseed oil or a mixture of red and white lead for this work.

(388) (*a*) (See Art. **759.**) A gate valve, since it gives a free passage to the water. The waterway of the globe valve is too contorted for use on water piping.

(*b*) (See Art. **754.**) Guard against the use of ground key bibbs for heavy pressures.

(389) (*a*) (See Art. **775.**) A flux is a substance which promotes the fusion of metals. It prevents oxidation of the heated parts.

(*b*) (See Art. **778.**) The flux is spread over the surface to be soldered for the purpose of promoting adhesion of the melted solder.

(*c*) (See Table 35, Art. **775.**) Chloride of zinc should be used. If the zinc were dirty, muriatic acid would be employed.

(390) (See Art. **781.**) The copper should be double-seamed, as shown at *A*, Fig. 200, the tinned side being on top. The seam should be well flattened down and soldered with half-and-half solder, as shown in the figure. Care must be taken to sweat the solder well.

(391) (*a*) (See Art. **787** and Table 36.) Length of joint, 3 in. Proportion same as Fig. 208.

(*b*) This joint may be much thinner than the above. It has no pressure to resist. Length is 2 in. (See Table 36.)

(*c*) (See Art. **788.**) The ends are squared, male end then chamfered off with rasp; female end plugged out with turn pin and rasped to an edge. Ends are then soiled to about 4 inches, and shaved to proper length to suit. Shaved portions are tallowed, then fixed securely in position, allowing room all around to work the hands. (See Fig. 209.)

(392) (See Art. **791.**) The defects shown at *F*, *G*, and *D* in Fig. 214 should be guarded against The bending pin should be held so as to drive the lead outwards, as shown in Fig. 212.

(393) (See Art. **799.**) The sheet lead is secured in the angle by tinned tacks or nails to prevent bulging. The solder is best applied with a pouring stick. The wiping should be begun on top, working downwards, and finishing at bottom. A tank iron may be used to maintain proper working heat. Use tallow as the flux. The solder of the finished seam must not overlap the soiled margins.

(394) (See Art. **805.**) An all-gas flame will tarnish the metal while heating it. The object of mixing air with the gas is chiefly to avoid the tarnishing effect, and to obtain a higher temperature.

(395) (See Art. **816.**) Pipe tacks are simply molded supports for pipes. They are usually cast in brass molds from old lead, with a little tin thrown in to harden them, or old wipe joints may be used. A pair of pipe tacks is shown in Fig. 231.

(396) (See Art. **657.**) Twenty ounces per square foot in weight.

$$\text{The cost} = \frac{96 \times 60}{144} \times \frac{20}{16} \times 28 \text{ cents} = \$14. \quad \text{Ans.}$$

(397) A mixture of lampblack, glue, and water. Rub grease off the surface with chalk. (See Art. **690.**) Heat soil and apply it as thin as possible with a stiff brush. If too much glue is present, the soil will peel off; if too little, it will rub off.

(398) The attachment required is a check-valve (see Arts. **760** and **761**) put on the pipe so that water may flow from *A* to *B* only. The swing check (see Fig. 194) is preferable.

(399) (See Art. **776.**) By placing zinc chips in muriatic acid. Hydrogen is liberated.

(400) "Sweating" means the act of soaking into the seam. (See Art. **781.**) Capillary attraction and the affinity of the metals are the powers which cause the sweating. The surfaces inside the seam must be free from tarnish to obtain good sweating.

(401) (See Art. **788.**) The heat is obtained by pouring the molten solder gently over the joint, at the same time holding the wiping cloth in such position that some solder will be caught in it and applied to heating the under side of the joint. The pipe outside of the joint should be well heated; otherwise, the solder will cool too quickly in wiping.

(402) (See Art. **792.**) This tool is commonly used to splash solder from the ladle upon a branch-joint until a sufficient depth of solder is obtained to prevent holes from being burned in the lead. Very useful for splashing upon thin pipes when the solder is hot enough to melt them; also, in places where the solder can not be poured from the ladle.

(403) (See Art. **799.**) The upright seams should be wiped first, their bases being finished along the bottom angles, as at *A* and *B* in Fig. 221. The bottom angles are then wiped. Guard against solder spreading too much.

Keep it ahead and well into the angles. Wipe from right to left, unless you are left-handed. Wipe close into the clean ing, and be sure to cover nail heads well.

(404) (See Art. **805.**) The flame will be tinged with yellow. A film of carbon, or soot, will be deposited upon the work.

(405) By lead bands (see Fig. 232, Art **817**), when in a vertical position. By wooden pipe shelves, when in a horizontal or inclined position.

(406) (See Art. **658.**) At 40° F., it is hard and brittle: at 275° F., it is malleable and ductile; at 400° F., it is again brittle.

(407) (See Arts. **693** and **694.**) An ordinary fitting has an internal diameter greater than that of the pipe. A flush fitting has an internal diameter equal to that of the pipe. The tightness of the joints in the ordinary fittings depends upon the complete filling of the tapered thread in the socket by the thread on the pipe, which is also tapered. The tightness of the flush-joint depends upon having a neatly fitting parallel thread, and the end of the pipe butting uniformly against the shoulder of the socket in the fitting.

(408) (See Art. **763.**) Use Fig. 196, and finish the grating flush with floor. This check-valve is always open until the water backs up in the drain and floats the valve *A*.

(409) (See Art. **777.**) Because the oxidized, or tarnished, surface of the metals will not readily take on solder, particularly if the solder is applied by the wiping process, in which tallow is the flux. Tallow does not remove or change an oxide. It facilitates the flow of the solder and prevents the cleaned surface of the lead from oxidizing.

(410) (See Art. **781.**) When the solder does not flow freely into the joint, or when a skin is being formed over the joint without proper adhesion. It is always too cold when it does not instantly melt solder.

(411) The process of wiping is that in which the solder is applied in a molten state by a ladle and formed into proper shape by a wiping cloth. (See Figs. 209, 210, 213, 215, and 218.) The working heat of the joint is obtained by the solder. Wiping is begun when the shaved surfaces are thoroughly tinned, the joint uniformly heated to proper temperature, and when enough solder adheres to the joint in a semi-liquid form. (See Arts. **787** and **788.**)

(412) (See **T Y** branch, Art. **793.**) The joint should not be made in the form of a **T**.

(413) (See locked or double seam, Art. **800.**) The seam will be the same as in *A*, Fig. 200, Art. **781.** Width of lock, about ½ inch.

(414) (See Art. **805.**) The flame will be short, ragged, and noisy. Too much air will reduce temperature of the flame and may carry unburnt gas with it.

(415) (See Art. **817.**) The pipes will sag between the points of support. The changes in temperature will facilitate this.

(416) Sheet iron coated with zinc. (See Art. **659** and Table 25.)

$$\text{Weight of a sheet} = \frac{30 \times 72}{144} \times 1.32 = 19.80 \text{ lb.} \quad \text{Ans.}$$

(417) Packed unions are those which require washers of some kind to make them water-tight. (See Figs. 155 and 157.) Their tightness depends upon a uniform compression of the packing between the faces of the parts. Ground unions depend upon a close contact of the metallic parts without packing, as in Fig. 156. Use a 3-inch flanged union.

(418) The safety and vacuum valve, or these valves separately, will prevent bursting or collapsing of the boiler. (See Arts. **764** and **765.**)

(419) (See Art. **777.**) File the point of the hot bit to a distance of about 1 inch; then rub the cleaned surface with sal-ammoniac and solder.

(420) (See Art. **782.**) By a floated seam. The edges of the sheet are beveled, shaved, and butted together to form a **V** joint, as in Fig. 201.

(421) (See Art. **788.**) Great care must be taken in finishing off, as in Fig. 210, that the pipe is not cut or otherwise injured by taking off the surplus metal at *a*. In throwing off the surplus solder tangentially, try to throw it on the paper under the joint.

(422) (See Art. **794.**) Flange joints are shown in section in Fig. 217. Care must be taken to prevent the wainscoating from being scorched, by inserting paper back of flange. A splash stick may be used for throwing on the solder. Guard against solder flowing into back of flange. Soil edges of flange.

(423) (See Art. **800.**) Seeing that the tank iron will be used, the margins around the wipings should be protected by paper pasted on the copper. The seams, then, would be wiped same as lead. The copper should be overlapped or double-seamed, and secured by tinned nails to the woodwork every 2 or 3 inches.

(424) (See Art. **805.**) A bluish-green color.

(425) By pipe straps, shown in Fig. 233. The straps are made of wrought iron (tinned). They are screwed to woodwork. Wall hooks, if the pipe runs against a brick or stone wall. Hangers, if the pipe is suspended from ceilings.

(426) The burr is used in riveting soft sheet metal, such as copper. The object in using it is to distribute the pressure, due to upsetting the shank, over as great an area as possible; also, to compress the sheets between the rivets and prevent their bulging apart. The button-head rivet is best adapted for riveting seams of cylinders subject to heavy pressures. (See Art. **661.**)

(**427**) The chief flaw in such castings is irregularity of thickness, due to the core being buoyed up by the pressure of the molten metal in the molds. Another flaw often occurs at the points where the different streams of flowing metal unite. (See Art. **708.**) By sounding the pipe with a small hammer.

(**428**) The pressure due to the head of water would be $325 \times 12 \times .03617 = 141$ lb. per square inch, and in order to secure a pressure of 25 pounds in the building, a pressure-reducing valve should be used. (See Art. **767.**)

(**429**) The tinning will be burned; that is, it will be converted into an oxide by the high temperature. (See Art. **777.**)

(**430**) By the floating of a seam is meant the process of smoothing the surface of the solder by the application of heat. The hatchet bit is commonly used in this work. (See Art. **782.**)

(**431**) The rapid cooling of a joint the instant that it is wiped prevents the tin from running to the bottom. It also gives it a glossy surface by chilling the tin and causing it to stay there. (See Art. **788.**)

(**432**) The end of the ferrule is filed, coated with resin, then soiled and tinned. The lead pipe to which the ferrule is to be secured is soiled, shaved, and fluxed with tallow, then pushed through the ferrule and doubled over, as shown in section, Fig. 218, and finally wiped, as shown in elevation in the same figure. Guard against slipping the ferrule in the end of the lead pipe.

(**433**) Copper lining, 16 to 20 ounce. Lead lining, 7 lb. (See Art. **801.**) The copper must be tinned.

(**434**) The edges of the metal are fitted and cleaned. The sheets are then laid in a horizontal position and closely butted, and held solidly in position by iron wire or other means. Hard spelter is then sprinkled over the seam and borax over that. Heat is then applied by the compound

blowpipe, as shown at A in Fig. 227, until the spelter fuses and flows, or sweats, into the seam. The blowpipe, then, is instantly removed. (See Art. **806.**)

(435) Hangers that will keep the pipe out from the walls, so that it can be properly cleaned. (See Art. **822.**)

(436) (*a*) (See Table 26, Art. **663.**) Lead pipe. $3.5 \times 26.5 = 92.75$ lb. Ans.

(*b*) (See Table 28, Art. **664.**) Lead waste pipe. $8.75 \times 2 = 17.5$ lb. Ans.

(*c*) (See Table 29, Art. **664.**) Block tin pipe.

$$\frac{37.25 \times 4}{16} = 9 \text{ lb. } 5 \text{ oz.} \quad \text{Ans.}$$

(437) (*a*) (See Art. **742.**) With dummies, as in Fig. 180, or bobbins, as in Fig. 182. Sand stretches the heel too much.

(*b*) With sand (see Art. **742**), or with a well-lubricated spiral steel spring (see Art. **743**); either way. Make bend easy, so as not to thin the heel too much.

(*c*) Bend over the knee, without filling. (See Art. **741.**)

(*d*) Fill pipe with melted resin or lead, and bend around a prepared block. (See Art. **744.**)

(*e*) Heat pipe to redness and bend while hot. (See Art. **745.**) Guard against kinking or flattening the bend by using a curved block which will prevent pipe from spreading.

(438) (See Table 33, Art. **770.**) The lead and tin will be heated above fusing point and will melt and flow together, while the copper will remain solid in the alloy, because its temperature of fusion is greater than 700° F.

(439) (*a*) Soiling is to prevent the solder from adhering to the metal at the parts soiled. (See Art. **779.**)

(*b*) About 2 to 3 inches wide beyond the shaving of the joint.

(*c*) About ½ to 1 inch wide. (See Art. **779.**)

(440) (See Art. **783.**) Bevel the ends of the pipes, soil to about $\frac{3}{4}$ inch, and shave the beveled part; then butt them together perfectly and tack with solder at intervals; then fill the **V** groove with solder and float it in a horizontal position, revolving the pipe at the same time. Guard against the defect shown at *a* in Fig. 203.

(441) (See Art. **789.**) To reflect an image of the joint to the eye of the workman. (See Fig. 211.)

(442) It should be made of lead and cut to such a pattern that when turned up it will form a frustum of a cone around the pipe. (See Fig. 219, Art. **796.**)

(443) (See Art. **801.**) They are used in supporting sheet lead against flat surfaces. There should be at least two in each side and one in each end piece.

(444) (*a*) (See Art. **809.**) The sketch will be similar to Fig. 228, and the names will be the same. Guard against rust joints. Cast-iron soil pipe sockets are too thin to resist the tensile strains set up by expansion of the rust.

(*b*) (See Art. **679.**) Use extra heavy.

(445) It should be supported at its base by an elbow with a heel rest cast on, as shown in Fig. 234, and supported laterally by wall hooks under each socket or by bands around each socket, as explained in Art. **823.**

(446) According to Table 30 in Art. **667,** the weight of standard $1\frac{1}{4}$-inch pipe per lineal foot is 2.258 lb.; consequently, $\frac{169.35}{2.258} = 75$ ft. Ans.

(447) In the construction of the plug cock, the waterway is opened full by turning the plug one-fourth of a revolution, and when closed it is maintained water-tight by the close contact of the plug and the body of the cock. In the compression cock, a number of revolutions of the stem are required to open the valve full, and when closed it is maintained water-tight by the compression of the valve

against its seat. Use a compression bibb for water under high pressure, because the plug cock is too liable to leakage through imperfect contact with the barrel. The compression bibb tends to prevent water hammer by slowly bringing the flowing water to rest. (See Arts. **747** to **749**, and **753.**)

(**448**) (See Table 34, Art. **771.**)

(*a*) Alloy, 1 zinc, 1 copper. Temperature of fusion = 550° F.

(*b*) Alloy, 1 lead to 2 of tin. Melts at 441° F.

(**449**) First file the tarnished coating from the parts to be soldered, then coat the parts with a flux (see Table 35, Art. **775**), and proceed to tin the surfaces as described in Arts. **777** and **778.** (See also Art. **780.**) The grade of solder best adapted for copper bit work is half-and-half.

(**450**) (See Art. **784.**) Prepare the ends and solder them as shown in Fig. 204. Guard against defects shown in Fig. 205. Use resin as the flux, and half-and-half as the solder.

(**451**) By closing both ends of the pipe so as to prevent a current of air through it which, of course, would cool the pipe. Maintain the temperature by a gasoline torch (see Fig. 167) or a tank iron (see Fig. 166).

(**452**) (*a*) (See Arts. **784** and **797.**) The pipe ends are prepared the same as for a cup joint. (See Fig. 204.) The ends are then put together and fluxed; half-and-half solder is melted into the cup, allowed to flow around the joint, and sweat thoroughly by the application of heat from the blowpipe flame, as shown in Fig. 220.

(*b*) When the flame E is noiseless as it is being blown against the joint.

(**453**) It is non-corrosive, is easily kept clean, and is durable. (See Art. **801.**)

(**454**) (See Art. **810.**) Use joint runners and pour from behind the socket.

(455) (See Art. **825.**) The rests should be 5 feet apart; that is, under each hub, as shown in Fig. 236. As a heel rest is used for the stack, the pipe rests chiefly serve to prevent lateral motion.

(456) (*a*) (See Art. **667.**)

(*b*) (See Art. **667.**) Butt-welded is $1\frac{1}{4}$ inches and under. Lap-welded is $1\frac{1}{2}$ inches and over.

(457) (See Art. **755.**) Water hammer will result.

(458) (See Art. **772.** For ingredients see Table 34.) The ingredients are 2 parts of tin to 3 of lead; consequently, their respective weights are $\frac{2}{\cancel{5}_{1}}$ of $\frac{\cancel{10}^{2}}{1} = \frac{4}{1}$, or 4 lb. of tin, and $\frac{3}{\cancel{5}_{1}} \times \frac{\cancel{10}^{2}}{1} = \frac{6}{1}$, or 6 lb. of lead. Ans.

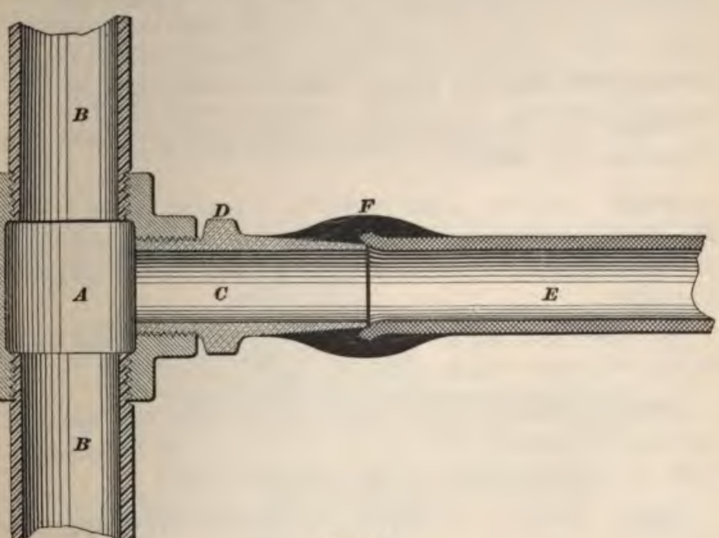

FIG. 14.

(459) (See Art. **780.**) Care must be taken not to melt the lead or tin by the application of too much heat.

The difference between the temperature of fusion of the solder and that of the metals to be soldered is very small.

(460) (See solder nipple joints, Art. **785,** and Fig. 151, Art. **691.**) In Fig. 14 *A* is a cast-iron **T** fitting; *B*, *B* are wrought-iron pipes; *C* is a brass solder nipple with hexagonal shoulder *D*; *E* is a lead pipe; *F* is a wiped solder joint.

(461) (See Art. **790.**) Tap a hole in the main pipe with the tap borer shown in Fig. 160, then open the hole outwards, with the bending pin, as shown in Fig. 212, until it exactly fits the tapered end of the branch pipe, which is prepared same as *A* in Fig. 208. The pieces are then shaved and secured in position, and the joint wiped as in Fig. 213.

(462) For thin tubes, etc., made of metal having a very low temperature of fusion; block tin, for instance. Because the heat is under more control than that transmitted from copper bits, and there is less liability of burning holes in the metal. The center of heat can be applied to the solder, and the pipe will receive its heat from the molten solder.

(463) By the application of heat and the tools mentioned in Art. **802.**

(464) (*a*) The joint must be a calked joint, and as the lead waste pipe can not stand calking, its end is strengthened by a brass ferrule wiped on, as shown in Fig. 230.

(*b*) (See Art. **671.**) Flush fittings with screwed joints, so that the bore will be uniform.

(465) Since the bolt must be secured to the slab without entirely passing through it, we would use an expansion bolt, for reasons stated in Art. **826.**

(466) (See Art. **673.**) Seamless drawn tubing is the strongest, because it has no brazed joint.

(467) A ball-cock, the principles of which are described in Art. **757,** would be used.

(468) The zinc in the filings would alloy with the solder and spoil it for wiping purposes. It can be fairly purified by the method given in Art. **773.**

(469) That its weight or mass be sufficient to retain a reasonable amount of heat and thus avoid reheating too often. (See Art. **780.**)

(470) A joint in which the solder has its surface finished by overcasting with the copper bit; that is, the floating process is done across the joint. The overcast joint is used chiefly for joining small brass couplings, etc., to lead tubes (see Art. **786**), or, in fact, any copper-bit joints which are too wide to float.

(471) The sections will be same as Fig. 214, the defects at *B*, *D*, *F*, and *G* being omitted.

(472) (*a*) Copper tinned on the inside, and sheet lead. (See Art. **798.**) Sheet tin, galvanized sheet iron, etc., are not durable.

(473) (*a*) (See Table 34 in Art. **771.**) Hard solder is an alloy of zinc, copper, and silver, used for joining metals having a high temperature of fusion.

(*b*) Brazing.

(474) (See Art. **814.**) A lead flange *a* should be wiped on the lead pipe *b*, as shown in Fig. 15, so that the

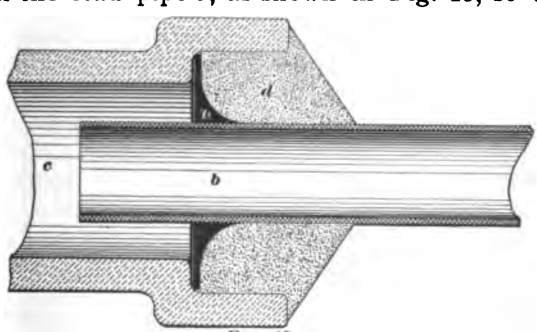

FIG. 15.

cement *d* can not be pushed inside the fireclay pipe *c*. The

surface of the lead pipe should be scratched and grease removed to allow the cement to adhere.

(475) Upon the solidity of the oakum packing and the complete filling of the socket after the joint is calked. (See Art. **809.**)

(476) (*a*) A cast-iron pipe 5 feet long, furnished with a socket cast on one end and a spigot on the other. As the pipe comes from the mold, it is called plain. When covered with rust preventatives, it is said to be coated. (See Art. **678.**

(*b*) Asphaltum or its compounds. (See Art. **683.**) The pipe should be heated, then dipped in the liquid.

(477) (See Art. **758.**) Attach the valve in such a way that the valve disk will close against the pressure; that is, the flow of water will be through the valve, as shown by the arrows in Fig. 190. The objection to the globe valve is that there is too much resistance to the free flow of water through it.

(478) Coarse solder has a chalky appearance, and fine solder is bright. (See Art. **774.**) Coarse solder can be made finer by the addition of block tin.

(479) By conduction through the molten solder at the point of the bit. The object of tinning a copper bit is to cause a close contact between the hot copper and the solder in the joint, so that heat will be transmitted rapidly from the copper to the solder; consequently, to the metal to be joined. (See Arts. **780** and **777.**)

(480) (See Art. **787.**) That the soiled surfaces be properly soiled; and the shaved surfaces thoroughly shaved and fluxed with tallow; that the solder be at the proper temperature and of proper composition; that the solder be poured gently and uniformly over the joint and part of the soiling outside of it; that the shaved surfaces be thoroughly tinned and the solder in a semi-molten condition before wiping is commenced; that there be enough heat in the

joint to allow the operator a reasonable length of time to finish wiping; that the joint be wiped to the edge of the cleaning and finished quickly before the metal has time to set, and that at the instant the wiping is finished it be rapidly cooled with air or a fine spray to prevent the tin running to the bottom.

(481) (*a*) Seeing that the lead lining is already in the tank, the seams should overlap one another. They are prepared as follows: Edges are nailed every two inches; they are then shaved to a distance of about $\frac{3}{4}$ inch on each side and soiled to a width of about 3 inches on each side; when soil is dry, the cleaning is rubbed with tallow as a flux. (See Art. **799.**)

(*b*) (See Art. **790** and Fig. 213.) Be careful to have the parts properly fitted and fixed solid; otherwise, molten solder is liable to flow inside and choke the pipe.

(482) (*a*) (See Art. **681.**) Vitrified or salt-glazed; because the glaze makes the pipe impervious to water.

(*b*) No; because made ground will always settle more or less, and the pipes will be broken and leak.

(*c*) Earthen drain pipes are liable to leakage, and if run near a well or other source of water supply, the leakage of sewage is liable to soak through the ground and contaminate the water.

(483) (See Arts. **803** to **805.**) The compound blowpipe.

(484) Since the copper roof leader is thin and pliable, like a lead pipe, a calked joint can not be made without the use of a sleeve, or ferrule; consequently, the connection would be similar to Fig. 230. Guard against putty or cement joints.

(485) (See Art. **734.**) Because it retards the flow of fluids through the pipe. The tool used for this work is called a reamer. (See Fig. 177.) It reams the orifice into a frustum of a cone, and thereby overcomes the evil effects of the *vena contracta*.

(486) (*a*) A pipe made of fireclay or earthenware, in 2 or 3 foot lengths, having a socket on one end and coated over with a salt glaze which is burned on its entire surface except inside the socket and over the plain end. The object of having these parts unglazed is to allow the cement, of which the joints are made, to adhere to the fireclay. Cement will not adhere properly to the glassy surface. The object of glazing is to make the pipe impervious to water and gases. (See Art. **680.**)

(*b*) (See Art. **666.**) The effect of the unavoidable expansion and contraction of the pipes is to work the lead rings out of the sockets and thus cause leaks. Wrought-iron pipe with screwed joints should be used.

PLUMBING AND DRAINAGE.

(QUESTIONS 487–584.)

(487) (See Art. **833,** *Absorption of Gases in Water.*) When the main is emptied it becomes filled with air, and when water is turned on a quantity of air will be absorbed by the water. When the water is heated it will give out a little air, which will gather in the top of the boiler or the pipes connected to it. At this point the water is saturated, and when the pressure is reduced, such as when the water is drawn off hot at the faucet, more air will be liberated in the form of minute globules, which gives the water a milky appearance. These globules rise slowly to the surface, and the water, consequently, clarifies at the bottom first.

(488) (See Art. **847.**) The expansion pipe, which is run from the top of the boiler to above the tank, is furnished with a corresponding return pipe, so that circulation can be obtained and the water in the expansion pipe thus heated. When this column is heated, the water-line in the expansion pipe will rise above that in the tank. (See Fig. 244, Art. **842.**) The end of the expansion pipe is doubled over the tank at such a height that when the water in the boiler or expansion pipe reaches a certain temperature, say 180° F., some will overflow into the tank and be replaced by cold water flowing into the boiler.

(489) (See Art. **857.**) By running a brass or copper pipe coil through the boiler, as shown in Fig. 253. An auxiliary heater of some description should be connected to the boiler to heat the water during summer. One of the simplest and perhaps the best is that shown in Fig. 253 at *H*. The steam coil must run along the bottom of the boiler, because only that water above the coil will be heated by it.

(490) By basin clamps. (See Art. **883** and Fig. 269.) Set the slab with plaster of Paris. Guard against bedding in oily putties. Height of slab from floor, about 2 ft. 6½ in.

(491) (See Art. **901.**) The trap inlet, which is practically inaccessible to the average person, is usually neglected, and, consequently, becomes foul.

(492) They are flushed with water from small tanks overhead, a separate tank being used for each closet. The tanks are set about 6 ft. above the closet bowls. (See Art. **913.**)

(493) (See Art. **925.**) The seal of the trap is the distance *A B*, Fig. 303.

(See Art. **878.**) Fig. 264 shows a round bowl with overflow horn.

(See *bottle trap*, Art. **927.**) *G* is the overflow; consequently, the trap and basin combined will be as shown here in Fig. 16, the height *S* being the seal.

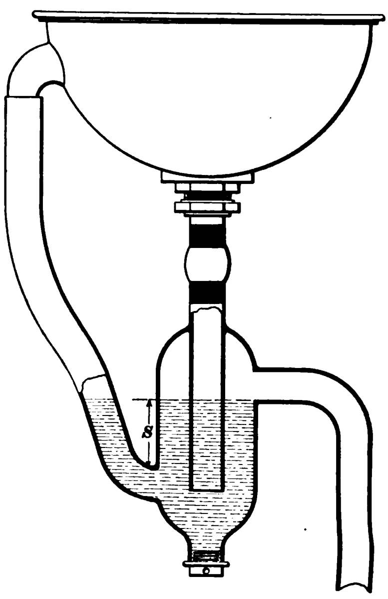

FIG. 16.

Guard against connecting the overflow, as shown here in Fig. 17, because drain air will enter the building through the overflow pipe *a*, as shown by arrows. (See Art. **927.**)

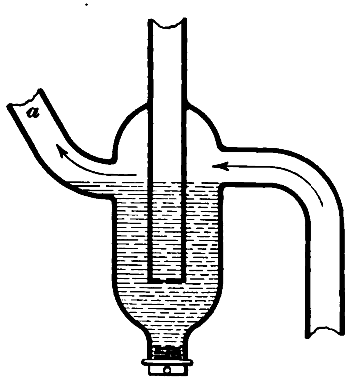

FIG. 17.

(494) (See Art. **952.**) Increase the diameter to 4 inches, as the pipe passes through the roof. The intersection is made water-tight with a lead flashing. (See Fig. 321.)

(495) (See Art. **834.**) They are used to deaden the shock to which lines of pipes are sometimes subject.

(496) When water lies in the reservoir, it càn only absorb 4 per cent. of its volume of air, because it is under atmospheric pressure only. It will double this quantity with every increase in pressure of 1 atmosphere. (See Art. **833.**) Consequently, $4 \times \frac{88}{14.7} = 24$, nearly, = percentage of its volume of air that the water is capable of absorbing at that pressure.

(497) See *fire-box coil*, Art. **849.**

(498) (See *circular wooden tanks*, Art. **859.**) Cedar wood is commonly used. They are made of staves, which are hooped just like a barrel. The hoops are drawn up tight by adjusting clamps and bolts. They are not usually lined.

(499) (See Art. **884.**) Have the nozzle of the cock pointing towards center of basin. Use lead washer under slab. Set cock in plaster of Paris. Guard against using any kind of oily putties; they stain marble. Set to a height of about 2 ft. 7 in. from top of slab to floor.

(500) (See Art **902.**) It derives its name from the method of flushing. Siphonic action is started by a jet of water, and the contents are siphoned from the bowl.

(501) (See *siphon tank*, Arts. **915** and **914.**) A constant and positive flush of a stated volume will be obtained, independent of the space of time the flush, or tank, valve is open.

(502) (See *ball trap*, Art. **928.**) Seeing that the bath will be very seldom used, a ball trap should be employed, so that, if the water should evaporate, the ball will form a good gas check.

(503) (See Art. **954.**) Ventilate from crown of each trap.

(504) The selection of a lining which will be insoluble in water, so that the water stored in the tank will not be charged with metallic poisons. Sheet copper tinned on the surface in contact with the water, forms a good safe lining. (See Art. **858.**)

(505) See *water hammer*, Art. **835.**

(*a*) Since the closing of the cock is rapid, the water in the pipe will be suddenly put to rest, and the momentum of the entire moving body of water in the pipe will be expended upon the cock and the pipe, the result being that the lead pipe will be swelled out a little with each shock and will finally burst.

(*b*) To bring the water to rest slowly by the use of air chambers and slow-closing compression valves.

(506) (See Arts. **850** and **851.**) A water-back having a heating surface of about 160 to 180 square inches, and a boiler having a capacity of 60 gallons. These, of course, are only approximate sizes.

(507) (See Art. **860** and Fig. 254.) The planking must be prevented from spreading with the hydrostatic pressure by the use of braces set at right angles to the planking. A wrought-iron tie-rod should pass through center of tank and be made water tight by a lead or copper pipe casing *a* wiped to the tank lining *b*, as shown here in Fig. 18. The tie-rod *c* passes through the planking

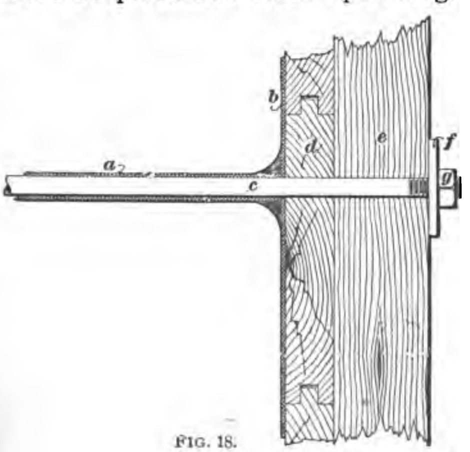

FIG. 18.

d and post or brace *e*. A nut *g* bearing on a fish-plate or a large washer *f* prevents *d* and *e* from bulging outwards.

(508) See Art. **905.**

1. The plunger chamber, which is not flushed, and is not accessible for cleaning, becomes foul.

2. The plunger valve often leaks, and the water, consequently, wastes away.

(509) One method is by the use of a ball cock. (See Art. **917.**) Another method is the slow-closing closet valve, Fig. 297. The ball cock maintains a uniform water-line, and if the plunger valve leaks, water will flow from the ball cock equal to the extent of the leak. A closet so supplied is not a water-waste preventer. Should the plunger leak when a closet is furnished with a valve similar to Fig. 297, the basin will become empty.

(510) (See *bell trap*, Art. **929.**) This form of a trap should never be used.

(511) (See Art. **955.**) Place at a point sufficiently high to cause water to show in fixture if waste pipe is choked.

(512) (See Art. **858.**) A sheet-metal safe, having its edges turned up from 3 to 4 inches and furnished with a safe waste pipe.

(513) (See *water hammer*, Art. **835.**) The water flows rapidly both ways to fill the partial vacuum caused by the instantaneous condensation of the steam bubbles, and water hammer takes place.

(514) (See Art. **852.**) Single-riveted boilers for low or moderate pressures; double-riveted boilers for extra heavy pressures.

(515) (*a*) By a ball-cock. (See Art. **864.**) This maintains a nearly constant water level in the tank.

(*b*) The delivery pipe should turn over the tank, as shown at *H* in Fig. 222, Art. **801.**

(*c*) (See Art. **864.**) Strainers should be employed to prevent the entrance of leaves, twigs, etc.

(**516**) (See Fig. 273, Art. **886.**) Since a running trap is to be used, it would be connected up as shown here in Fig. 19. It is vented at *a*. Guard against placing trap between overflow pipe *b* and waste outlet to bath. The pipes passing through the safe *c* should have flange joints wiped as at *d*, *e*, and *f*, to make the safe water-tight. A soft waste pipe *g*,

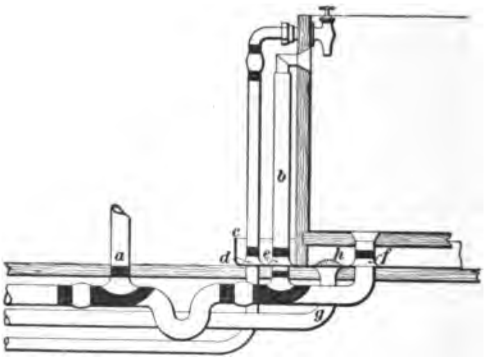

FIG. 19.

furnished with a raised brass strainer *h*, is provided to carry off any leakage to a safe point.

(**517**) (See Arts. **894** and **895.**) In order to obtain water at the proper temperature, a mixing pipe must be employed. The hot and cold valves must deliver into the mixing pipe, and the mixing pipe into the sprays or other nozzles. Thermometers should be attached to mixing pipes.

(**518**) (See Art. **906.**) Contents of pan by falling into the trunk displace an equal volume of foul air in the trunk, thereby causing it to flow into the closet apartment. The gases in trunk at the same time diffuse rapidly with the air of the apartment.

(**519**) (See *periodical flushing tank*, Art. **918.**) Set the supply cock so that the pan will tilt every 5 minutes.

(520) (See Art. **932.**) Trap the waste pipe to prevent the cold air in the refrigerator from flowing out. Drain air and foul air from any source must not enter a refrigerator.

(521) (See Art. **958.**) To obtain a nearly uniform flow, give pitches shown in Table 38.

(522) (See Art. **858.**) Attend to the lining used.

(523) (See Art. **836.**) In this connection, the street main *B* (see Fig. 240) will be connected as shown by *E H F G D*, and the pipe *A* and corporation cock *C* will be omitted from the sketch. *E* and *H* will be $\frac{3}{4}$ in.; *F* will be 1 in. or $1\frac{1}{4}$ in.; *G* and *D* will be $1\frac{1}{4}$ in. Do not connect the lead pipe on straight; make an offset.

(524) (See Art. **853.**) Sketch same as Fig. 249, omitting dotted line *a b* and cock *C*.

(525) (See Art. **864.**) Overflow pipes should be used in all tanks.

Telltale pipes should be used when tanks are filled by pumps.

Telltale pipes should be connected about $\frac{1}{4}$ in. below the overflow pipes.

The standing overflow with plug and socket should be used in tanks where sediment will accumulate, and requires to be periodically washed out. This pipe avoids the bad practice of running off muddy water at the fixture faucets when the tank is being emptied and cleaned.

(526) (See Art. **889.**) The valves should be attached outside the bath, and only the nozzle or shell inlet allowed to project inside.

(527) (See Art. **907.**) They should be provided with a flushing rim, and should be flushed from a small tank overhead.

(528) (*a*) (See Art. **919.**) The arrangement shown in Fig. 299 may be employed. Since the chain *A* is attached to the closet seat, and the flush box *F* discharges its contents

through the flush pipe *G* when the weight is taken off the seat, the closet will be flushed automatically.

(*b*) In railroad stations, etc., where they are very liable to neglect.

(529) (*a*) (See Art. **930.**) Trap each fixture separately, except laundry tubs. One trap is sufficient for a set of two or three tubs. Traps should be placed as close to fixtures as possible.

(*b*) (See Art. **933.**) Usually placed in cellars, for easy access. Guard against frost. Give them a deep seal to prevent too much loss by evaporation.

(530) (See Art. **958.**) Large pipes are not usually self-cleaning. They require a great volume of water to cleanse their sides. The depth of water flowing through them with ordinary flushes is too shallow to properly float solids forwards.

(531) See Art. **937.**

(532) (See Art. **837.**) The shut-off cock or valve should be so constructed that, when closed, the pipe between the nozzle and the valve will be drained empty to prevent freezing.

(533) (See Art. **853.**) The water is liable to be siphoned out of the boiler to a depth below the water-back, and as the fire is allowed to remain in the range, the water-back will then become overheated (perhaps, heated to redness), and if the boiler is being filled while the water-back is in this condition, a dangerous explosion is liable to be the result. A small hole should be made in the top of the boiler tube to admit air to break siphonic action.

(534) See Arts. **865** to **867.**

(535) (See Art. **887.**) Although very convenient for cleaning-out purposes, they are, nevertheless, objectionable because they occupy too much valuable space and are in the way of the bather.

(536) A closet having its trap exposed to the frost can not be used. A long hopper (see Art. **907**) may be employed; its trap may be placed underground and clear of frost.

(537) See Art. **920.**

(538) (See Art. **934.**) Grease will solidify upon the inside of the pipe and finally close the bore. Use grease intercepters.

(539) (See Art. **959,** and Fig. 328.) About $\frac{3}{4}$ full.

(540) (See Art. **949.**) It is a light check-valve sealed in mercury. It is used in cases where fixtures can not easily be back-vented.

(541) (*a*) Avoid cutting the beam near the middle of its length; that is, the center of the span. Notches may be cut near the points of support of the beam without material injury.

(*b*) Bore a hole through the center of the depth of the beam, and pass the pipe through it. This part is the neutral axis of the beam, and is not subject to stresses as are the fibers above and below it.

(542) By this method of connecting up a boiler, the flow pipe from water-back should join the hot-water distributing pipe close to the top of boiler, as shown in Fig. 250, Art. **854.** Probably the chief objection to this method is that circulation between water-back and boiler will be stopped if the water is shut off the building and the pipes drained. Guard against dropping the hot-water distributing pipe down from top of boiler without a branch being taken from its highest point, because air, liberated from the water while it is being heated, will accumulate over boiler and stop circulation between water-back and boiler.

(543) (See *oval and flat-bottomed pantry sinks*, Arts. **868** and **869.**) Do not neglect countersunk wooden shelf for the flat-bottomed sink.

(544) (See Arts. **887** and **888.**) The standing waste and overflow is shown connected up in Fig. 275.

(545) (*a*) (See Art. **897.**) Leakage, rot, and odor.

(*b*) (See Art. **897.**) They are difficult to keep perfectly clean, owing to the sharp corners, which accumulate soap and dirt.

(546) See Art. **908.**

(547) (See Art. **921.**) For trough closet, use perforated pipe to flush sides of trough, and a large jet at highest end of trough to force solids into the drains. A flushing tank should be fitted up 5 or 6 feet above the trough to do all the flushing periodically. The siphon in it may be started by the tilting of a smaller tank within it (see Art. **918**), or by a siphon arrangement, as shown in Fig. 332, Art. **963,** the tank, of course, being supplied by a small, steady flowing stream of water, such as from the city mains. The trough must be disconnected from the sewers by a 4 or 5-inch trap.

(548) (See Art. **947.**) Attach a vent pipe to the crown of the trap, as shown at *a* in Fig. 317.

(549) (See Art. **960.**) Lay perfectly straight, with a good, uniform pitch. Have a smooth internal surface, flush joints inside, and support the pipes well by packing underneath them. Do not disturb the pipes while the joints are setting.

(550) (See Art. **953.**) Ice will form inside the pipe; cover the pipe with some non-conducting material.

(551) (See Art. **840.**) The effect is to check or entirely stop the flow of water through the pipe.

(552) (See Art. **854.**) Run a circulation pipe from the highest point of the hot-water supply pipe to basin. This point must be near the basin in order to obtain hot water the instant the basin cock is opened.

(553) (*a*) At the foot of the bath. (See Fig. 275, Art. **888.**)

(*b*) At the back of the bath. (See Fig. 276, Art. **890.**)

(554) In the accompanying Fig. 20, three tubs will be fitted up just the same as the two shown in Fig. 281, Art. **897,** with this difference (see Fig. 20): The trap will be connected to the outlet of the left-hand tub. The water pipes, as shown by dotted lines, will extend to the third tub. A 3-inch pipe stack will be shown, as at *A*, and a $\frac{3}{4}$ **S** trap (see *C* in Fig. 304, Art. **926**) will join the stack by means of a **Y** branch (see *A* in Fig. 320, Art. **952**) and a brass ferrule connection. (See Fig. 218, Art. **795.**) The back-vent pipe *B* will join the stack in a similar manner, the branch being set above level of bottom of tubs. A trap

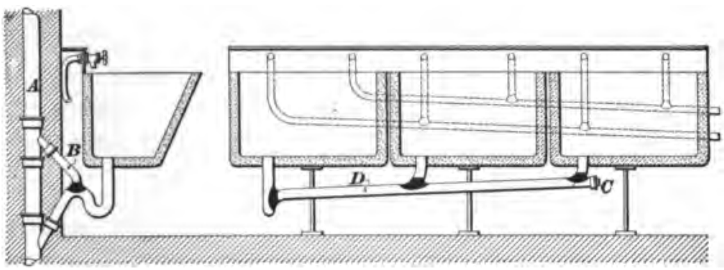

FIG. 20.

screw may be wiped in the end *C* to facilitate cleaning the waste pipe *D*.

(555) (See Art. **909.**) Use a brass floor flange, as shown in Fig. 289. Be careful not to screw the bolts down too tight; otherwise, the porcelain flange on the closet will break.

(556) (See *urinals*, Art. **922.**) Fit up a treadle urinal, as in Fig. 301. Provide a spray tube for cleansing the treadle box.

(557) (See Art. **931.**) If the trap under the floor is not removed and a bend put in its place, the new closet will be double trapped, which is objectionable.

(558) (See Art. **961.**) They are useful for inspecting the interior of drains; also, for easy access when drains

become choked; should be placed at the point where a drain changes its direction, where a branch enters a main drain, or at suitable distances along a straight line of drain pipe.

(559) (*a*) A pressure gauge (see Art. **828**), as the pressure of the water is greater than that of the atmosphere.

(*b*) A vacuum gauge (see Art. **830**), because the pressure of the water in the suction pipe of a pump placed 20 feet above the water must be less than that of the atmosphere.

(*c*) The difference in pressure will be $60 + 11 = 71$ lb. per sq. in., because the pressure gauge indicates in pounds per square inch above atmospheric pressure, while the vacuum gauge indicates in pounds per square inch below atmospheric pressure. Ans. $= 71$ lb.

(560) (See Art. **842.**) The heated particles rise, while the colder particles tend to replace them.

(561) (*a*) (See Art. **855.**) Usually where there is no space available to stand a vertical boiler.

(*b*) The return pipe to the water-back should connect to bottom of boiler in order to feed water-back with the coldest water; also, to cause all the water in boiler to be heated and prevent a stratum of cold water from lying "dead" in the bottom of the boiler. The feed to the boiler should also join at or near the bottom; otherwise, the cold water entering the boiler will cool the hot water too much by mixing with it. An improved method of connecting is shown here in Fig. 21. The arrows show the direc-

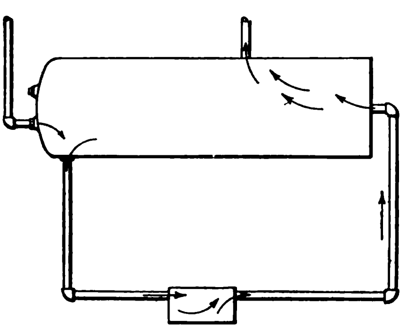

FIG. 21.

tion of the main currents when hot water is being drawn at the fixtures.

(562) (*a*) See Arts. **873, 875,** and **876.**

(*b*) See Art. **877.**

(563) (*a*) By combination cocks located at the foot of the bath, either inside or outside, the latter being preferred, as shown in Figs. 274 and 275.

(*b*) By combination cocks located at the back of the bath, and outside of it, as shown in Fig. 276.

(564) See Art. **898.**

(*a*) Above the tubs and at the back of them; attached to a special board, as shown in Fig. 281.

(*b*) Within the tubs, and secured to the back of them near the top.

(565) (See Art. **909.**) On the house side of the seal, the object being to prevent leakage of drain air by a defective joint.

(566) (See Art. **924.**) Sewer gas is generated when the sewage matter decomposes.

(567) (See Art. **957.**) The local vent pipe should be run in a hot place, inside or close to a constantly hot chimney, for instance, so that a good draft may at all times be obtained.

(568) (See Art. **963.**) A flushing apparatus, as shown in Fig. 332, may be employed. The stream may flow into the tank direct, or by a tilting tank.

(569) See Art. **831.**

(*a*) To a height of $\frac{38}{.43404} = 87$ ft. $6\frac{1}{2}$ in., nearly, vertically above the gauge.

(*b*) No; because under the most favorable circumstances there would only be about $2\frac{1}{2}$ feet head to cause a flow at the fixture; this is too small to give a good flow.

(570) The boiling point of water is increased with increase in pressure. (See Art. **844**; also the table of Properties of Steam.)

(571) See Art. **856.**

(*a*) Should be made of copper, tinned on the surfaces in contact with the water. A double boiler is used, because one water-back only will do the heating.

(*b*) This sketch will be similar to Fig. 252. Guard against placing sediment cocks *L* and *M* in such a position that the inner boiler can be emptied while the outer one is full.

(572) See Art. **899.**

(573) (See Arts. **911** and **912.**) If there is any danger of the flush pipe or the closet being jarred, a flexible connection should be employed.

(574) (See Art. **925.**) The vertical distance between the tongue of the trap and the water level is called the seal. A round pipe **S** trap is shown in Figs. 317 and 318. Fig. 317 is sealed, and Fig. 318 is unsealed.

(575) (See Art. **950.**) If less than 5 feet long, they are usually made of lead; if longer, they are usually of iron, terminating in short lead ends.

(576) (See Arts. **941** to **943.**) A blow-back may occur either by a heavy discharge of water into the system, or by wind pressure.

(577) (*a*) The iron is corroded; some of the oxides are soluble, and some insoluble. The insoluble oxides go to discolor the water. (See *solvent action of water*, Art. **832.**)

(*b*) Lead is also corroded, and the compounds formed, being soluble in water, can not be detected by the senses when present in small quantities only. This solution is very poisonous. (See Art. **832.**)

(*c*) The zinc coating of galvanized-iron pipes is affected

by water the same as lead, and the compounds formed are also poisonous. (See Art. **832.**)

(*d*) The block-tin lining of pipes is practically unaffected by potable water; consequently, the water contained by such pipes is almost unaffected.

(578) (*a*) (See table of Expansion of Water, and also rule, Art. **846.**)

$$\text{Original volume} = 60\text{ gal.} = 60 \times 231 = 13{,}860\text{ cu. in.}$$

$$\text{Final volume} = \frac{13{,}860 \times 1.04340}{.99989} = 14{,}463.1.$$

Consequently, cubical expansion = 14,463.1 − 13,860 = 603.1 cu. in. Ans.

(*b*) Volume of water in pipe divided by sectional area of the pipe = height of the water above the boiler.

$$\frac{603.1}{1.5^2 \times .7854} = 341.27\text{ in., or 28 ft. } 5\tfrac{1}{4}\text{ in., nearly. Ans.}$$

(579) See Art. **856.**

(580) See Arts. **878** to **881**, and Figs. 265 to 267.

(581) (See Art. **900.**) Proper depth of seal, about $1\frac{1}{2}$ in. or $1\frac{3}{4}$ in.; same depth in deepest part of basin.

(582) See Art. **913.**

(*a*) A good flush will drive the solids out of the basin and through the trap.

(*b*) Color the water in the basin, and throw in some crumpled paper; then, flush the closet. If the paper is forced into the drainage system, and the colored water in the basin and the trap is entirely replaced with clean water, the flush may be said to be good.

(583) (See Art. **927.**) They are not self-cleansing. The water can not be completely renewed with every flush. They should not be used for closets or urinals.

(584) The closet *a* in the question being a front outlet washout (see Fig. 282), and shown in elevation, its trap is not seen. It is there, nevertheless, and its vent horn should be connected to a branch calked on the soil-pipe stack, as shown here in Fig. 22. In order to properly ventilate the bath waste, a back-vent pipe should be run up over the door to join the stack, as shown at *g*. It will make bad work to take a vent pipe from the crown of the bath trap and run it along under the floor, as waste water will be forced into it. Should the bath waste become choked, the back-vent, in such a case, would act as a waste pipe without being observed, and this is objectionable. (See Art. **955.**) There are many different ways of arranging the work properly, and the accompanying Fig. 22 shows one of them.

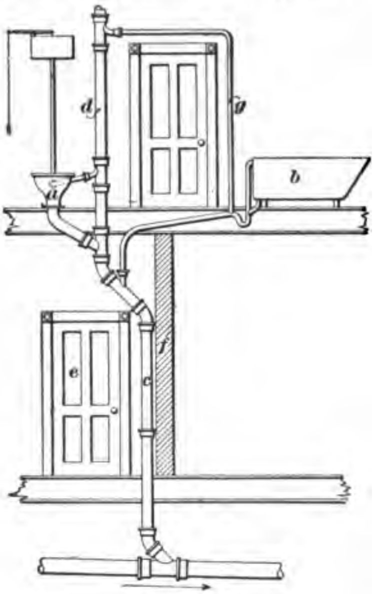

FIG. 22.

PLUMBING AND DRAINAGE.

(QUESTIONS 585–652.)

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(585) (*a*) See Art. **965.**

(*b*) It is usually attached to the machine and close to the gas generator.

(586) (*a*) (See Art. **971.**) Check the air first, then reduce the gas supply.

(*b*) (See Art. **971.**) Shut off the air first, then the gas.

(587) See Art. **983.**

(588) (*a*) and (*b*) See Art. **993.**

(*c*) No; iron pipes will not swell out as much as lead pipes, and, hence, can not take up the expansion of the water while it is being converted into ice. Ordinary iron pipes can not resist the expansive force, and they split rather than become enlarged.

(589) See Art. **999.**

(590) Water flowing with such a velocity will soon wear away the brickwork. (See Art. **1007.**)

(591) See Art. **1013.**

(*a*) Dam up the stream so as to form a little pond, and thus obtain a suitable head to operate a hydraulic ram. The head should be about 5 feet or more; length of drive pipe, 40 feet or more. The exhaust water from the ram should flow into the stream below the dam. House in the ram and

protect the pipes against frost. The drive pipe should be straight and funnel-mouthed.

(*b*) See Art. **615.**

(*c*) (See Art. **1013.**) Use separate drive pipes. Connect each ram separately to the delivery pipe.

(*d*) Two gate valves upon each ram; one on the drive pipe, and one on the delivery pipe. The rams will thus be independent of each other.

(592) (See Art. **1024.**) Hot water will ruin the hard rubber parts of the ordinary water meter. A meter should be used which has its working parts made of brass or bronze, or the hot water must be prevented from entering the water.

(593) (See Arts. **1033** and **1034.**) The process is called "aeration."

(594) (See Art. **964.**) The seams should be burned together. Plumbers' solder is not suitable.

(595) (*a*) (See Art. **968.**) By a set of bellows or a blower.

(*b*) The blast must be steady, of a uniform pressure, and give a constant supply.

(596) See Art. **972.**

(597) See Art. **983.**

(*a*) A little more calking will remedy the defect.

(*b*) The pipe or fitting should be renewed.

(*c*) The pipe should be renewed.

(*d*) The flaw should be removed; that is, the casting should be renewed.

(598) (See Art. **992.**) That part of the pipe in the cellar is accessible; consequently, it may be thawed by the use of a gasoline torch. Apply the heat at the end

of the ice plug and gradually melt the ice inwards so that the water when heated may have room to expand. Use a small steam generator and a block-tin steam tube to thaw the underground pipe. Provide generator with a safety valve.

(599) See Art. **1003.**

(600) See Art. **1007.**

(*a*) About 1 in 240.

(*b*) Flushing tank at the highest end.

(601) See Art. **1014.**

(*a*) An air chamber or some other cushion should be provided at the base of the delivery pipe to cause an easy and uniform discharge.

(*b*) If this is neglected, the mill will thump and pound, and probably hammer itself out of condition. The piston rod is very liable to be pulled apart.

(602) See Art. **1024.**

(603) See Art. **1035.**

(*a*) The first washing of the roof and gutters should not be permitted to enter the cistern.

(*b*) By the use of a "cut-off."

(604) See Arts. **964** and **965.**

(605) See Art. **969.**

(606) (See Art. **972.**) Upon the size of the bead and its adhesion to the lead.

(607) (*a*) See Arts. **984** and **985.**

(*b*) After the fixtures are set, so that the trap seals and fixture connections may be all tested.

(*c*) About 1½-inch water column.

(608) See Arts. **994** and **995.**

(*a*) By grease accumulations.

(*b*) Brass screw-caps at most convenient points.

(*c*) By the use of rattan canes.

(609) See Art. **1004.**

(610) See Art. **1008.**

(*a*) The floor gutters should be trapped.

(*b*) Proper strainers should be supplied, as shown in Fig. 352.

(611) (*a*) See Arts. **1020** and **1021.**

(*b*) It is safe to operate by any domestic servant, is almost noiseless, consumes but little fuel, and requires very little attention.

(612) See Art. **1028.**

(613) See Art. **1036.**

(*a*) A low velocity is necessary, so that the water may be in contact with the filtering medium for a reasonable length of time.

(*b*) The filter should be self-cleansing, or, at least, easily cleaned; otherwise, it will soon become worse than useless through neglect.

(614) (See Arts. **965** and **966.**) The gas is generated by the decomposition of the water. The machine is charged with sulphuric acid, commercial zinc, and water. The perforated bottom and the open tube *d*, as shown in Fig. 334. The pressure in *b* can not possibly exceed that due to a head of the liquid in *d* and *a*, unless *d* is plugged up tight. The height of the column is just adapted to a good working pressure.

(615) See Art. **969.**

(*a*) An explosive mixture is very liable to be formed within the mixing pipe.

(*b*) At the nozzle. This will prevent an air and gas mixture in the tubes.

(616) See Art. **973,** and Fig. 339.

(*a*) The lead stick is chiefly employed to lay a body on the seam, or joint; also, to fill up interstices.

(*b*) It is chiefly used upon butt seams, or joints. Lap seams are usually fed by the metal forming the lap.

(617) See Art. **986.**

(*a*) Pour 3 to 5 ounces of oil of peppermint down the vent stacks on the roof. Follow this with hot water, then close all open ends. The test is most searching when a slight pressure is put upon the system.

(*b*) Leaks are detected by the odor of oil of peppermint which passes through the leaks.

(618) (See Art. **996.**) A flue tube should be run from the apartment to the outer atmosphere, say above the roof. Inlet to tube should be funnel-mouthed, and the gas jet should be located under it so that the air in the flue will be heated and a good draft obtained.

(619) (See Arts. **1004** and **1005.**) The form shown in Fig. 351 is preferable, since the volume of discharge is so variable. The special advantage is that, with a minimum volume of discharge, a maximum depth can be obtained.

(620) (*a*) (See Art. **1009.**) Since water is abundant and the pressure high, an automatic cellar drainer may be employed.

(*b*) (See Art. **1010.**) The small jet of water delivered with high velocity carries with it a large volume of the cellar water, and forces it up to a point sufficiently high for it to fall by gravity into the sewer.

(621) (See Art. **1022.**) Since the man who will operate the pump is a gardener, and, consequently, not familiar with machinery, a simple and safe engine should be employed. The Rider compression engine (see Fig. 356) is specially adapted for this work, and is extensively employed when the height the water has to be raised exceeds 75 or 100 feet.

(622) Since the bath branch and the sink branch are each $\frac{3}{4}$ inch in diameter, the 1-inch pipe should be run along as

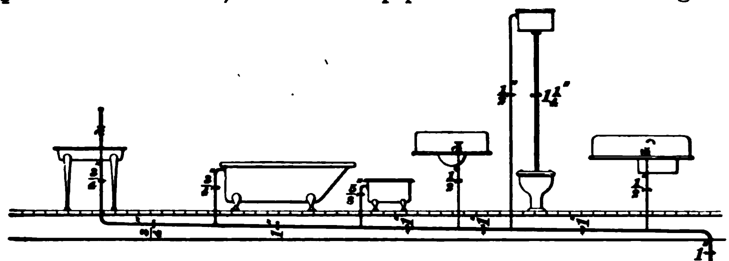

FIG. 23.

shown, and reduced only for the sink. (See Fig. 23, shown here.)

(623) See Art. **1037** and Fig. 363.

(624) (See Art. **966.**) To prevent an explosive mixture of air and hydrogen being formed within the chamber. It is accomplished by entirely filling the gas generator with the liquid.

(625) Yes; the gas in the machine is hot, and is highly charged with watery vapor when it blows through the water in the fire trap. As the gas flows through the tubes, it cools, and the vapor is condensed on the inside of the tubing. The water of condensation is liable to reach the blowpipe and extinguish the flame, or it may accumulate in kinks in the tubing and so close the caliber.

(626) See Arts. **974** to **976**; also, Figs. 340 to 342.

(627) (*a*) They should be run against or inside the inner walls, which are protected from freezing. (See Art. **989.**)

(*b*) The pipe should be protected against frost by a suitable covering of non-conducting material. (See Art. **989.**)

(628) (*a*) See Art. **997.**

(*b*) (See Art. **997.**) Salt-glazed spigot and socket pipes, 6 inches in diameter, bedded in and jointed with Port-

land cement and sand. If the sewer connection is to be laid in "made ground," 5-inch or 6-inch extra heavy asphalt-coated cast-iron spigot and socket pipes would be employed. These would be jointed with lead and oakum.

(629) (*a*) (See Art. **1005.**) Above the springing of the top arch, as shown in Fig. 351.

(*b*) (See invert *A* in Fig. 351.) This should be salt-glazed on its inner surface.

(630) (See *chain pumps*, Art. **1011.**) They aerate the water and thus help to prevent its becoming stale and flat.

(631) (*a*) (See Art. **1022.**) By a stream of cold water being caused to flow through a water-jacket under and around the leathers.

(*b*) (See Art. **1022.**) To supply air to the compression cylinder, and thus compensate for any air lost through leakage.

(*c*) (See Art. **1022.**) To absorb heat from the hot air as it flows from the heater to the cold chamber, and to emit heat to the same air as it returns from the cold chamber to the heater.

(*d*) (See Art. **1022.**) The oil will work into the cylinders, bake hard on the inside, and finally jam the pistons. This will stop the engine.

(*e*) (See Art. **1022.**) It should be set upon a solid foundation and be perfectly plumb.

(632) (See Art. **1031.**) The sizes of the branches should be greatest at the upper floors and smallest at the lower floors, in order to obtain a uniform supply throughout. (See Fig. 362.)

(633) See Art. **1038.**

(634) (*a*) (See Art. **967.**) Zinc of the ordinary commercial quality. Pure zinc is too sluggish and too costly.

(*b*) (See Art. **967.**) Three ounces of zinc will furnish 1 cu. ft. of machine gas; consequently, $40 \times 3 = 120$ ounces

will be required to generate 40 cu. ft. of gas, or $\frac{120}{16} = 7.5$ lb., say 8 lb. Ans.

(635) (See Art. **970.**) Ignite the hydrogen first, then regulate the air supply until the flame is steady and noiseless, well pointed, and the inner flame well defined.

(636) (See Art. **977** and Fig. 343.) The flame is fed by the lead overlap.

(637) (See Art. **989.**) When the ice is being formed, the water expands about $\frac{1}{9}$ of its volume, and if there is no room for the expansion, the pipe must burst.

(638) (*a*) (See Art. **998.**) They become foul very rapidly. If built water-tight, they require too much attention. If constructed loose, on the filtering plan, the interstices of the brickwork or masonry soon become cemented up with grease, etc.

(*b*) The sewage matter soon contaminates the earth all around and thereby affects the purity of the water in any wells in the vicinity of a cesspool. Some wells are actually poisoned by sewage from cesspools. The extent of well contamination will depend upon the distance the well is from the cesspool and the nature of the ground.

(*c*) (See Art. **998.**) Typhoid fever, diphtheria, and scarlet fever, chiefly.

(639) See Art. **1006.**

(*a*) The natural tendency is a downflow of the sewer air towards the outlet, because the sewer air is colder, that is, more dense than the atmosphere.

(*b*) The tendency is for the sewer air to ascend in the sewage system and flow out of the higher open ends, because it is warmer, consequently less dense, than the atmosphere.

(640) (See Art. **1011.**) To guard against suffocation by entering a well laden with obnoxious or dangerous gases. Carbonic acid gas is commonly met in deep wells. A lighted

lantern lowered into the well is a simple test for the presence of this gas.

(641) (*a*) See Art. **1023.**

(*b*) See Art. **1024.**

(642) (See Art. **1033.**) By passing the water through a thick bed of fine sand, or some other matter which will strain the water.

(643) (*a*) (See Art. **1038.**) One objection is that leaks are liable to do much damage to the rooms underneath. Another objection is the noise usually made by water flowing through the pipes.

(*b*) (See Art. **1038.**) Above kitchens, sculleries, pantries, etc., so that both of the above objections will be overcome.

(644) See Art. **967.**

(*a*) Becomes heated.

(*b*) Heat facilitates the liberation of the hydrogen.

(*c*) The sulphate of zinc will crystallize and probably clog the machine.

(645) (See Art. **970.**) The non-oxidizing part of the flame, that is, the inner flame.

(646) See Arts. **979** to **981.**

(*a*) Since acids are to be stored in the tank, the seams should be burned. Since as few seams should be used as possible, sheets must be thoroughly supported with "bull's-eyes," etc.

(*b*) The end sheets are best secured in place acid-tight, as shown in Figs. 345 and 347.

(647) (*a*) (See Art. **990.**) It may freeze without bursting, if the water which is being displaced by the ice formation has room to flow into an area of lower pressure, such as back into the city mains or through a leaky faucet.

(*b*) (See Art. **991** and Fig. 350.) Ice plugs are formed within the pipe, and thus prevent easy expansion of the

water between the plugs. This wâter, upon solidifying, expands and swells, or bursts the pipe between the plugs.

(648) (See Art. **999.**) The sewer should have an air-relief pipe to prevent air locking if outlet is submerged.

(649) No; for reasons stated in Art. **1007.**

(650) (*a*) See Arts. **1011** and **1012;** also, Fig. 354.

(*b*) See Art. **1012** for the advantages and disadvantages of the method.

(651) (See Art. **1024.**) In order to find how many cubic feet of water have passed through the meter since it was last read, we subtract the last reading from this, which is $47{,}805 - 6{,}417 = 41{,}388$. Ans.

(652) (See Art. **1033.**) Bone charcoal.

GAS AND GAS FITTING.

(QUESTIONS 653–746.)

(653) See rule, Art. **1066.**

SOLUTION.—Volume discharged at the given pressure is 185 cubic feet. Multiplying this by $\sqrt{4}$, or 2, we have $185 \times 2 = 370$. Dividing this by $\sqrt{1.75}$, or 1.3229, we have $370 \div 1.3229 = 279.7$ cu. ft., nearly. Ans.

(654) According to the explanation given in Art. **1080,** the dial shown in Fig. 8, accompanying the question, reads 40,800 cu. ft. The difference between this reading and that in Fig. 378, Art. **1080** is

$$40{,}800 - 14{,}200 = 26{,}600 \text{ cu. ft. Ans.}$$

(655) See Art. **1089.** Each burner consumes about 5 cubic feet per hour; consequently, total amount of gas to be supplied per hour equals

$$27 \times 5 = 135 \text{ cu. ft.}$$

Referring to Table 41, we find that a 1-inch pipe will do the work. 1-inch pipe. Ans.

(656) See Art. **1104;** also, Art. **1071.**

(657) See Art. **1112.**

(658) See Art. **1135.**

(659) See Art. **1166.**

(660) (*a*) (See Art. **1185.**) About 240 candle power.

(*b*) Since acetylene has about 240 candle power, and common gas about 16 candle power, the number of gas burners required will be about $\frac{240}{16} = 15$. Ans.

(661) (See rule, Art. **1206.**) Main floor will require $\frac{65 \times 90}{40} = 146$ burners. Each balcony will require $\frac{1,200}{40} = 30$ burners. Total number of burners required $= 146 + 30 + 30 = 206$. Ans.

(662) (*a*) See Art. **1055.**

(*b*) See Art. **1055.**

(663) (See Art. **1068.**) Owing to the specific gravity of the gas being less than that of air.

(664) (See Art. **1081.**) Is used on large gas mains chiefly. They can only be used in places free from frost.

(665) (See Art. **1091.**) The water partly closes the bore of the pipe and thereby chokes the flow of gas.

(666) See Art. **1104.**

(667) See Art. **1114.**

(668) (See Art. **1136.**) Fire checks are used to prevent "blow-backs." To prevent the temperature of the air mixture below the flame from reaching the point of ignition.

(669) (*a*) See Arts. **1168** and **1169.**

(*b*) No. An atmosphere of 12 parts air and 1 part gas is an explosive mixture.

(670) See Art. **1186.**

(671) See Art. **1210.**

(672) See Art. **1056.**

(673) (See Table 40, Art. **1069.**) The increase of pressure for each 10 feet in rise is .073 inch of water. Consequently, the increase in pressure at the 18th floor will be $.073 \text{ inch} \times \frac{220}{10} = 1.6$ inches of water. The total pressure at the 18th floor will be $1.6 + 1.25 = 2.85$ inches of water. Ans.

(674) (See Art. **1082.**) Commonly employed on the service pipe inside the building. Frost does not affect it much.

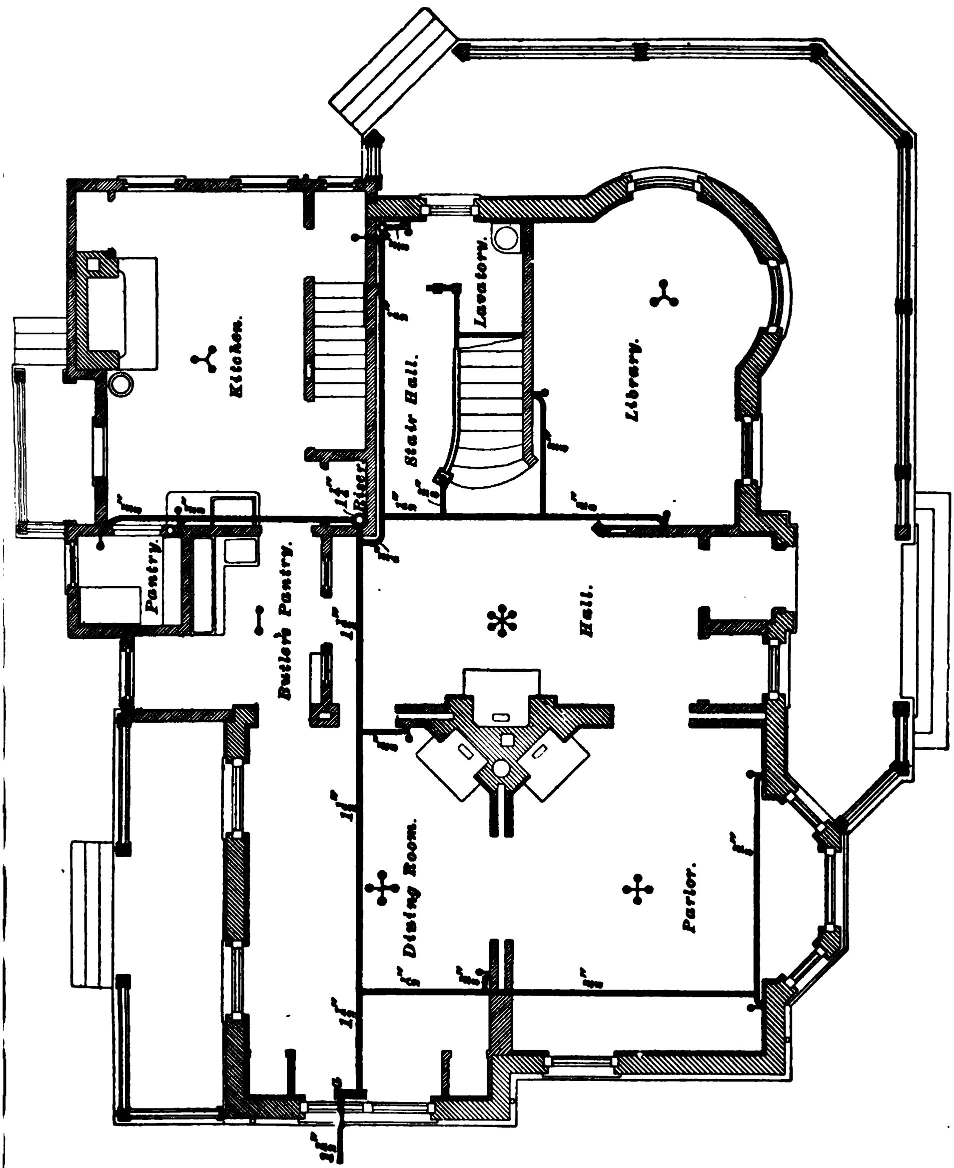
Kitchen.
Pantry.
Butler's Pantry.
Stair Hall.
Lavatory.
Library.
Riser
Hall.
Dining Room.
Parlor.

FIG. 24.

(675) (See Art. **1091.**) (*a*) Grade all pipes back to meter and place a siphon there.

(*b*) Place a siphon here at an accessible point and have a pet-cock convenient to empty it.

(676) See Art. **1105.**

(677) (*a*) See Art. **1115.**

(*b*) (See Art. **1115.**) To produce a current of air which will furnish enough oxygen to the flame to cause complete combustion.

(678) See Art. **1137.**

(679) (*a*) (See Art. **1171.**) Water in the pipes.

(*b*) Drain the siphons (if any) or blow sagged pipes.

(680) (See Art. **1187.**) Since $4\frac{1}{2}$ gal. of this gasoline will produce 1,000 cu. ft. of 15 c.p. gas, and since ten 5-foot burners will consume $10 \times 100 \times 5 = 5{,}000$ cu. ft. of gas in 100 hours, it follows that

$$4.5 \times \frac{5{,}000}{1{,}000} = 22.5 \text{ gals. of gasoline are required. Ans.}$$

(681) See Art. **1213.**

(682) See Art. **1057.**

(683) See Art. **1070.**

(684) (See Arts. **1084** and **1085.**) Ordinary governors operate only to regulate the pressure in the pipes. The volumetric regulator operates to control both pressure and volume.

(685) Fig. 24 shows how the piping in the basement may be arranged, also the sizes of the several pipes. Since the riser to the second floor is not changed, the piping shown in Fig. 386, Art. **1093,** will remain unchanged. Note the newel-post branch.

(686) See Art. **1105.**

(687) See Arts. **1117** and **1118.**

(688) See Art. **1139.**

(689) (See Art. **1173.**) The air-chamber stores the compressed air, and when the cock is opened suddenly it allows a large volume of air to flow through the pipe with high velocity.

(690) See Arts. **1188** and **1189.**

(691) (See table, Art. **1217.**) In this table, the distance, 20 inches, shows a candle power of 16; or, see Art. **1195;** since the intensity of light is inversely as the square of the distance from the source of light, it follows that the candle power of the gas flame will be $80^2 \div 20^2 =$ 16 times greater than that of the candle flame. The candle flame, being 1 candle power, however, it also follows that the gas flame is 16 candle power. Ans.

(692) Galvanized malleable-iron fittings for all pipes having a diameter less than 2 inches (see Art. **1060**) and cast-iron steam fittings for pipes of larger diameter.

(693) (See Art. **1073.**) One inch of mercury at $62° = .4897$ lb. per square inch. Consequently,

$$7.5 \times .4897 = 3.6727 \text{ lb. per sq. in. Ans.}$$

(694) (See Art. **1086.**) Economy, steadiness of flame, and effectiveness in operation.

(695) (See Art. **1095.**) Grade down to main, if possible.

(696) See Art. **1107.**

(697) See Art. **1120.**

(698) See Art. **1142.**

(699) (See Art. **1174.**) (*a*) Defective burners or excessively rich gas. Generally speaking, a lack of oxygen to the flame.

(*b*) Use thinner slits in such burners, so as to spread the flame more; or a chimney may be required to increase the passage of air over the flame.

(700) (*a*) (See Art. **1189.**) They should be located at a safe distance from buildings (not less than 50 feet) and should be buried under ground.

(*b*) (See Arts. **1186** and **1189.**) The temperature of the gasoline should be nearly uniform, both summer and winter, and this can best be obtained by burying the generator at least 5 feet deep in the ground.

(701) See Arts. **1214** and **1216.**

(702) See Art. **1063.**

(703) Would tap the main at a suitable point, then apply a Pitot's tube. (See Fig. 374, Art. **1074.**)

(704) Volumetric regulation is best adapted. (See Art. **1087.**)

(705) (*a*) (See Art. **1096.**) Set wet meter on solid shelf, and truly level in front and across. Connect up with lead pipe. Protect from frost. Set in accessible place.

(*b*) Same as above, only the shelf may be neglected in some cases, as these meters are light. In this case, place siphon near meter, as in Fig. 388.

(706) (See Art. **1107.**) Air is mixed with the gas before combustion.

(707) (*a*) See Arts. **1122** and **1123.**

(*b*) The Fletcher.

(708) (*a*) See Arts. **1143** and **1144.**

(*b*) No. It evaporates too freely. Glycerine is preferable.

(709) See Art. **1179.**

(710) See Art. **1190.**

(711) See Art. **1134.**

(712) (See Art. **1064.**) The volume delivered will be inversely as the square root of the length of the pipe.

(713) See example, Art. **1075.**

Solution.—Applying rule **II**, Art. **1075,**

$$750 \times (6 + 407) \div 408 = 759.2 \text{ cu. ft., nearly. Ans.}$$

(714) (See Art. **1087.**) Loss of time in adjustment. Irregularity of results. Clogging of the check.

(715) See Art. **1099.**

(716) (See Art. **1107.**) (*a*) It is called "regeneration."

(*b*) The intensity of the flame is increased, because the temperature of the flame is increased.

(717) (*a*) (See Art. **1124.**) By providing it with gauze, as shown in Fig. 402.

(*b*) Higher temperature flame; less liability of flame snapping out.

(718) See Art. **1149.**

(719) See Art. **1181.**

(720) (*a*) See Arts. **1188** and **1192.**

(*b*) Adjustable burners, such as the Argand, which must have a chimney. (See Fig. 393, Art. **1115.**)

(721) (*a*) See Art. **1154.**

(*b*) Yes.

(722) (See Art. **1064.**) The volume delivered will be directly as the square root of the pressure of the gas.

(723) See Art. **1077.**

(724) On the service pipe and near the meter. It should be adjusted to suit the pressure in the house-distributing system.

(725) (See Art. **1098.**) Guard against condensation in the main line *e*, Fig. 389, Art. **1099,** from entering *d*.

(726) (See Art. **1108.**) The part of the process in which the carbon particles are heated to incandescence.

(727) (See Arts. **1128** to **1130.**) Sufficient flue surface to allow the heat to be absorbed by the air currents. In Fig. 404, baffle plates are employed to cause the hot products to pass all over the surface, and thereby prevent a "short-circuit" to *d*.

(728) (*a*) See Art. **1151.**

(*b*) 4 inches.

(729) See Art. **1182.**

(730) See Art. **1195.**

(731) (See Art. **1185.**) (*a*) Acetylene.

(*b*) It is made from calcium carbide and water.

(*c*) No. It will smoke. The burners must have special thin slits to spread the flame.

732) (See Art. **1064.**) The volume delivered will be inversely as the square root of the density.

(733) See Arts. **1077** and **1078.**

(734) (See Art. **1088.**) Set governor so as to give a pressure of .5-inch water column at the burners.

(735) See Art. **1100.** (*a*) No.

(*b*) With non-conducting materials to keep in the heat.

(*c*) Guard against contact between the pipe and the wire. Insulate the pipe with rubber tape, as explained.

(736) See Art. **1110.**

(737) (See Art. **1133.**) A flue should be employed to carry off the products of combustion to the outer air. This will prevent vitiation of the air in the room.

(738) See Art. **1153.**

(739) See Art. **1183.**

(740) See Arts. **1197** and **1199.**

(741) See Arts. **1200** and **1201.**

(742) According to rule, Art. **1065.** Volume originally delivered is 185 cubic feet; multiplying this by $\sqrt{100}$,

or 10, we have $185 \times 10 = 1,850$ cu. ft. Dividing this by $\sqrt{271}$, or 16.47, nearly, we have $\frac{1,850}{16.47} = 112.32$ cu. ft., nearly. Ans.

(743) (*a*) (See Art. **1079.**) (*b*) By noting the difference in pressure between the supply and delivery to and from the meter.

(744) (See Art. **1089.**) One inch is the smallest safe size.

(745) (*a*) By air pressure. (See Arts. **1101** and **1102.**)

(*b*) By blowing vapor of ether into the system, the leaks being detected by smell or by the assistance of soapy water.

(746) (See Art. **1111.**) (*a*) Those gases having the largest amount of carbon in proportion to the hydrogen give off the most intense light.

(*b*) Acetylene, C_2H_2. (See also Art. **1185.**)

ELECTRIC-LIGHT WIRING AND BELL WORK.

(QUESTIONS 747–802.)

(747) See Art. **1223.**

(748) See Art. **1232.**

(749) The multiple-arc, or parallel, system, the multiple-series system, and the three-wire system.

(750) The ampere, the volt, and the ohm.

(751) See Art. **1297.**

(752) A steady current is maintained through the magnet coils of a vibrating bell, which, when interrupted, allows the bell to ring from an open-circuit battery.

(753) The number of lamps = 30 = N; the distance in feet = 100 = F; the drop in volts = 1.25 = E. By formula **1**, Art. **1280,** the resistance per foot of the wire

$$R_f = \frac{1.25}{30 \times 100} = .000417 \text{ ohm per foot} = .417 \text{ ohm per 1,000 feet.}$$

This corresponds to No. 6 B. & S. gauge. The current taken is $.5 \times 30 = 15$ amperes, which is safe; see Table 43. Ans.

(754) See Art. **1221.**

(755) The resistance per 1,000 feet is the given resistance divided by $\frac{3,540}{1,000} = 3.54$. $\frac{2.917}{3.54} = .824$ ohm.

By reference to Table 43, this is seen to be No. 9 wire. Ans.

(756) See Art. **1242.**

(757) See Art. **1219.**

(758) $6\frac{3}{8}$ in. $= 6.375$ in. $= 6,375$ mils. $6,375^2 = 40,640,625$ circular mils. Ans.

(759)

$$\begin{aligned} 3 \text{ lamps of } 50 \text{ c.p.} &= 9 \text{ of } 16 \text{ c.p.} \\ 8 \text{ lamps of } 32 \text{ c.p.} &= 16 \text{ of } 16 \text{ c.p.} \\ 32 \text{ lamps of } 16 \text{ c.p.} &= \underline{32} \text{ of } 16 \text{ c.p.} \\ \text{Total} \quad &= 57 \text{ lamps} = N. \end{aligned}$$

The drop in potential $= 5$ volts $= E$, and the distance in feet $= 340 = F$. Then, by formula **2,** Art. **1280,** the resistance per foot of the feeder will be

$$R_f = \frac{5}{57 \times 340} = \frac{5}{19,380} = .000258 \text{ ohm per foot} = .258 \text{ ohm per } 1,000 \text{ ft.}$$

This corresponds to No. 4 B. & S. wire; see Table 43. Ans.

(760) See Art. **1296.**

(761) When it is required to ring a bell continuously after the push-button is pressed.

(762) See Art. **1326.**

(763) (*a*) The initial voltage is first determined. By formula **1,** Art. **1291,** $V_1 = \frac{100 \times 110}{95} = 115.79$ volts. By formula **2,** the drop in potential $E = 115.79 - 110 = 5.79$ volts. The current $= 13.5$ amperes $= C$; the drop in potential $= 5.79$ volts $= e$. By Ohm's law, the resistance of the two conductors $= R = \frac{e}{C} = \frac{5.79}{13.5} = .43$ ohm. Ans.

(*b*) The resistance per foot $= \frac{.43}{2 \times 320} = .00067$ ohm. Ans.

(764) They may be used for a few lamps, such as those on an electrolier, or the lights in a small room.

(765) See Art. **1265.**

(766) The number of lamps $= 65 = N$; the distance $= 540$ feet $= F$; the drop in volts $= 4.5 = E$. Since the

voltage of the lamps is 110, and they are of 16 c.p., the resistance per foot of the conductor is, by formula **2,** Art. **1280,**

$$R_f = \frac{4.5}{65 \times 540} = .000128 \text{ ohm per foot} = .128 \text{ ohm per } 1{,}000 \text{ feet.}$$

From the wire table (No. 43, Art. **1227**), we find this to correspond with No. 1 B. & S. Ans.

(767) The weight of copper required is only $\frac{3}{8}$ of that necessary for the two-wire system.

(768) See Fig. 490, Art. **1299.**

(769) A battery of about six cells in series with a grounded spark-coil.

(770) The resistance per 1,000 feet of No. 6 wire is, by Table 43, .411 ohm; or, per foot, .000411 ohm $= R_f$. The four 32 c.p. lamps = eight 16 c.p lamps, and the total number is $45 + 8 = 53 = N$. The distance from the dynamo = 165 feet $= F$. Then, by formula, Art. **1286,** the drop

$$E = .000411 \times 53 \times 165 = 3.59 \text{ volts. Ans.}$$

(771) See Art. **1262.**

(772) See Arts. **1267, 1272,** and **1274.**

(773) The current required for the lamps is 36 amperes, since each 32 c.p. lamp takes 1 ampere. By reference to Table 43, it will be seen that No. 8 wire is not allowed to carry a larger current than 25 amperes, and it will, therefore be too small, and must not be used. Ans.

(774) The location of each box should be so chosen that the different circuits may all have a uniform fall of potential.

(775) See Art. **1300.**

(776) (*a*) No. 18 B. & S. gauge. (*b*) No. 14 or 16 B. & S.

(777) The circuit through any one lamp has a length of 166 feet, and the single distance = 83 feet $= F$; the

number of lamps $= 32 = N$. In finding the actual drop in volts, we make use of formula **1,** Art. **1291,**

$$V_1 = \frac{100 \times 110}{98.5} = 111.7 \text{ volts.}$$

Then by formula **2,** Art. **1291,** the drop in volts $E = 111.7 - 110 = 1.7$ volts. The resistance per foot of the conductor will be, by formula **2,** Art. **1280,**

$$R_f = \frac{1.7}{32 \times 83} = .00064 \text{ ohm per foot} = .64 \text{ ohm per 1,000 feet.}$$

The nearest size to this is No. 8, and the current being 16 amperes, this wire will be safe. Ans.

(778) See Art. **1230.**

(779) Glass or porcelain insulating tubes must be secured in the wall, and the wires should be passed through them.

(780) The initial voltage by formula **1,** Art. **1291,**

$$V_1 = \frac{100 \times 55}{100 - 2.5} = 56.41 \text{ volts.}$$

The drop in potential, by formula **2,** Art. **1291,**

$$E = 56.41 - 55 = 1.41 \text{ volts.}$$

The number of lamps is 10 of 16 c. p., and 3 of 32 c. p. = 16 lamps of 16 c. p. $= N$. The distance $= 110$ feet $= F$. Then, by formula, Art. **1284,** the resistance per foot

$$R_f = \frac{1.41}{2 \times 16 \times 110} = .0004 \text{ ohm per foot} = .4 \text{ ohm per 1,000 feet.}$$

This corresponds to No. 6 wire, which will safely carry the current, 16 amperes. Ans.

(781) See Art. **1301.**

(782) The circuit may include a relay, which will ring an alarm bell when the system is short-circuited.

(783) The number of lamps $= 240 = N$; the distance $=$ 135 feet $= F$; the drop $= 2$ volts $= E$. By formula, Art. **1289,** the area of the wire

$$A = \frac{10.8 \times 240 \times 135}{2} = 174,960 \text{ circular mils.}$$

This size is between Nos. 000 and 0000, and will, therefore, carry over 145 amperes; but the current is only 120 amperes, and the cable will be of safe capacity. Ans.

(784) See Art. **1237.**

(785) See Art. **1257.**

(786) The resistance per 1,000 feet of No. 6 wire is .411 ohm, or, per foot, .000411 ohm $= R_f$; the number of lamps $= 25 = N$; the distance $= 225$ feet $= F$. Then, by formula, Art. **1285,** the drop on the line

$$E = 2 \times .000411 \times 25 \times 225 = 4.624 \text{ volts. Ans.}$$

(787) See Art. **1304.**

(788) The insulation of the wires must be very perfect, and they should be well protected whenever they approach any grounded metal work.

(789) See Art. **1239.**

(790) The resistance per 1,000 feet of No. 4 wire is .259 ohm, or, per foot, .000259 ohm $= R_f$; the number of lamps $= 46 = N$; the distance $= 84$ feet $= F$. Then, by formula, Art. **1286,** the drop in potential

$$E = .000259 \times 46 \times 84 = 1.00 \text{ volt. Ans.}$$

(791) See Art. **1305.**

(792) See Art. **1260.**

(793) The 40 lamps present an equivalent of $3 \times 40 =$ 120 lamps of 16 c.p. $= N$; the length of feeder is 85 feet $=$ F; the drop in potential $= 1.25$ volts $= E$. Then, by formula **2,** Art. **1280,** the resistance per foot of the feeder

$$R_f = \frac{1.25}{120 \times 85} = .000123 \text{ ohm per foot} = .123 \text{ ohm per 1,000 feet.}$$

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This corresponds near enough to No. 1 wire. The current being 1.5 amperes per lamp $= 1.5 \times 40 = 60$ amperes, which is within the allowable limit, and is safe. Ans.

For the loop, the distance to be considered is one-half that measured round the dome. (See Art. **1288.**) The diameter of the dome is 120 feet, and the circumference is, therefore, 377 feet. The lamp-feet will then be $120 \times \frac{377}{2} = 22,620 = NF$. The drop of potential is 2.5 volts $= E$; and the resistance per foot of the conductor will be, by formula **2,** Art. **1280,**

$$R_f = \frac{2.5}{22,620} = .00011 \text{ ohm per foot} = .11 \text{ ohm per 1,000 feet.}$$

The nearest size of wire is No. 0, B. & S. Ans.

(794) See Figs. 460, 461, and 463.

(795) The number of lamps $= 66 = N$; the distance $=$ 180 feet $= F$; the drop $= 2.5$ volts $= E$. By formula **1,** Art. **1292,** the resistance per foot of the wire

$$R_f = \frac{2 \times 2.5}{66 \times 180} = .00042 \text{ ohm per foot} = .42 \text{ ohm per 1,000}$$

feet.

This corresponds to No 6 wire, and since the current will be $\frac{66}{4} = 16.5$ amperes, this size will be safe. Ans.

(796) All but one must be changed to give a single stroke.

(797) See Art. **1258.**

(798) By formula **1,** Art. **1291,** the initial voltage

$$V_1 = \frac{100 \times 110}{100 - 1.25} = 111.4 \text{ volts.}$$

By formula **2,** Art. **1291,** the drop in potential

$$E = 111.4 - 110 = 1.4 \text{ volts.}$$

Since it is evident that a large conductor is required, its area is calculated by formula, Art. **1289,**

$$A = \frac{10.8 \times 480 \times 80}{1.4} = 296{,}000 \text{ circular mils.}$$

By interpolation in Table 46, Art. **1290,** it will be found that this cable will carry 269 amperes, and it is, therefore, safe. Ans.

(799) See Art. **1309,** Fig. 500.

(800) By formula **1,** Art. **1291,** the initial voltage

$$V_1 = \frac{100 \times 55}{100 - 4.6} = 57.65 \text{ volts.}$$

By formula **2,** Art. **1291,** the drop in voltage

$$E = 57.65 - 55 = 2.65 \text{ volts. Ans.}$$

(801) See Art. **1270.**

(802) According to formula **1,** Art. **1291,** the initial voltage

$$V_1 = \frac{100 \times 220}{97} = 226.8 \text{ volts.}$$

By formula **2,** Art. **1291,** the drop

$$E = 226.8 - 220 = 6.8 \text{ volts} = E.$$

The number of lamps $= 84 = N$; the distance $= 320$ feet $= F$. Then, by formula **1,** Art. **1292,** the resistance per foot of the wire

$$R_f = \frac{2 \times 6.8}{84 \times 320} = .000506 \text{ ohm per foot} = .506 \text{ ohm per 1,000 feet.}$$

The nearest size of wire is No. 7, which will carry 30 amperes. Since the current taken by the lamps is only one-half of that required in the ordinary two-wire system, it will be $\frac{84 \times .5}{2} = 21$ amperes, and the wire will be safe. Ans.

PRINCIPLES OF HEATING AND VENTILATION.

(QUESTIONS 803–882.)

(803) See Art. **1472.**

(*a*) Chiefly of two gases, oxygen and nitrogen.

(*b*) Mixed; held in diffusion.

(*c*) Oxygen.

(804) See Art. **1397.**

(805) Examine mercury column for uniformity, and find the boiling and freezing points; then, count 180 divisions between, as explained in Art. **1388.**

(806) (*a*) (See Arts. **1375** and **1376.**) By heating the steam in a chamber void of water.

(*b*) Superheated steam.

(807) (See rule, Art. **1362.**) Coefficient of expansion $= .0000823$. Increase in temperature (see table of Properties of Saturated Steam) $= 307° - 60° = 247°$. Consequently, $250 \times 247 \times .0000823 = 5.082$ in. Ans.

(808) (*a*) (See Art. **1345.**) A substance which will permit radiant heat to pass through it.

(*b*) Dry air and other common gases.

(*c*) (See Table 47, Art. **1346.**) Rock salt.

(809) See Art. **1445.**

(810) See Art. **1483.**

1. By adding heat to the liquid.

2. By removing or lessening the pressure.

(811) Down draft, induced by the induction cowl shown in Fig. 573, Art. **1466.** Up draft, accelerated by use of any of the cowls, Figs. 571, 572, or 574 ; or automatic

cowls may be used, the induced current cowl having its vane v, Fig. 575, reversed.

(812) (See Arts. **1334** to **1336.**) Heat is a form of energy. Temperature is a measure of the velocity of the molecules of a body as they vibrate to and fro.

(813) See Art. **1348.**

(*a*) The transmission of heat by radiation is instantaneous; conduction is simply retarded transmission, the time required being measurable.

(*b*) A good conductor is a body through which heat is rapidly transmitted, while a poor, or a bad, conductor is one through which heat travels slowly. Silver, copper, iron, and nearly all the metals are good conductors, while hair felt, asbestos, wood, wool, etc., are called bad conductors.

(814) (See rule, Art. **1365.**) $20 \times .23751 \times 160 = 760.032$ B. T. U. Ans.

(815) (See Example 7, Art. **1379.**) The latent heat (see column 4 of the table of Properties of Saturated Steam) for a temperature of 228° is about 955 B. T. U.; consequently, $70 \times 955 = 66{,}850$ B. T. U. are given off by the condensation of the steam. Ans.

(816) See rules given in Arts. **1392** and **1393.**

(*a*) $45 \times \frac{9}{5} + 32 = 113°$ F.

(*b*) $\frac{5}{9}(70 - 32) = 21\frac{1}{9}°$ C.

(*c*) $\frac{9}{5} \times -10 + 32 = -18 + 32 = 14°$ F.

(817) See Arts. **1412** to **1414.**

(*a*) Use thermometer cup.

(*b*) Place cup in center of current. (See Fig. 537.)

(*c*) Mercury is best.

(*d*) Heavy engine oil.

(818) (See rule and example, Art. **1425.**) Volume of air is $120 \times 4 = 480$ cu. ft. Original weight (see Table 55,

Art. **1423**) $= 480 \times .08635 = 41.448$ lb., and the absolute temperature is 460°.

Applying the rule,

$$\frac{41.448 \times 460}{460 + 100} = 34.0466 \text{ lb.}$$

The change in weight $= 41.448 - 34.0466 = 7.4014$ lb. Ans.

(819) (See Art. **1441.**) Place a short tube over register face to prevent current from spreading. Find velocity by moving anemometer to and fro across the current. Find volume by multiplying velocity by sectional area of the tube.

(820) (See Art. **1448.**) Since the change of direction is made in 1.5 seconds by the sharp bend, and in 3 seconds by the easy bend, then, $3^2 \div 1.5^2 = 4$ times as much force will be required when turning the curve of the shorter bend; consequently, $\frac{3}{4}$ lb. will be saved. Ans.

(821) See Art. **1458.**

(822) (See Art. **1337.**) According to the modern theory, the molecules composing the body are in a state of vibratory motion. The application of heat increases the motion, and the molecules are forced further apart. Two prime effects are increase in temperature and change of volume.

(823) No (see Arts. **1349** to **1351**); it depends chiefly upon the nature of the surfaces for absorbing and transmitting heat.

(824) See example and rule, Art. **1367.**

Applying this rule,

$$10 \times .23751 \times 10 = 23.751;$$
$$20 \times 1 \times 200 = 4{,}000;$$
$$23.751 + 4{,}000 = 4{,}023.751;$$
$$10 \times .23751 = 2.3751;$$
$$20 \times 1 = 20;$$
$$20 + 2.3751 = 22.3751, \text{ and}$$
$$4{,}023.751 \div 22.3751 = 179.83°. \quad \text{Ans.}$$

(825) (See Example 8, Art. **1379.**) To raise the temperature of 100 lb. of air through 180° requires $100 \times 180 \times .23751 = 4,275.18$ B. T. U. Since the water of condensation drains away, the latent heat of the steam only can be employed to heat the air; therefore, $\frac{4,275.18}{954.814} = 4.4775$ lb. = weight of steam required. Ans.

(826) (*a*) No (see Art. **1396**); the liquid will boil.

(*b*) No; the liquid will freeze.

(827) (*a*) See Art. **1417.**

(*b*) See Fig. 541.

(828) See Art. **1426.**

(829) See Art. **1442.**

(*a*) It is used to measure air pressures.

(*b*) No; it indicates pressure only.

(830) (See Art. **1449.**) Loss of energy.

(831) See Art. **1461.**

(*a*) and (*b*) Accelerated draft.

(*c*) Retarded, or down, draft.

(832) (See Art. **1339.**) At this temperature the molecules are forced so far apart that they are no longer attracted towards each other by the force of cohesion, and the water is, consequently, changed into what we call steam.

(833) No (see Art. **1352**); because the quantity of heat radiated from the polished surface would be very small. (See Table 50.)

(834) (See Art. **1369.**) Heat required to change the ice into water at the same temperature =

$$20 \times 142.65 = 2,853 \text{ B. T. U.}$$

Heat required to raise the temperature of 20 lb. of water from 32° to 212°=

$$20 \times 180.531 = 3,610.620 \text{ B. T. U.}$$

Heat required to convert the water into steam at 212° =

$$20 \times 966.069 = 19,321.380 \text{ B. T. U.}$$

Total heat required =

$2,853.00 + 3,610.62 + 19,321.38 = 25,785$ B. T. U. Ans.

(835) (*a*) Thermometers. (See Art. **1385.**)

(*b*) Calorimeters. (See Art. **1415**; also Art. **1384.**)

(836) See Art. **1476.**

(837) See example, Art. **1419.**

$$\frac{3.5}{3.5 + .75} = .8235, \text{ or } 82.35 \text{ per cent. Ans.}$$

(838) (See example, Art. **1428.**) Table 51, Art. **1359,** shows that water at 170° exerts a pressure of $\frac{60.783}{144} = .4221$ lb. per sq. in. at base of column for each foot in height, and that water at 210° has a corresponding pressure of $\frac{59.820}{144} = .4154$ lb. per sq. in. Consequently, difference in pressure per foot of height $= .4221 - .4154 = .0067$ lb. per sq. in., and $.0067 \times 50 = .3350$ lb. per sq. in. = the total difference. Ans.

(839) (See Art. **1443.**) Light pressures are noticeable because of the slight difference in the density of the liquid in the columns.

(840) See Art. **1450.**

(841) (See Art. **1485.**) Yes; the warm air will soon become saturated with moisture, and evaporation will then cease. The moisture-laden air must be removed and replaced with more dry, warm air, in order to have continuous vaporization of the liquid in the wet clothes.

(842) See Art. **1340.**

(843) See Arts. **1353** to **1355.**

(*a*) By convection.

(*b*) No; the particles heated by the flame would not descend and heat the cold particles under them, and, as water is a bad conductor, steam would be formed on the surface while the water underneath would remain cold. Heat must be applied to the bottom or the water must be forced to circulate.

(844) See rule and example, Art. **1372.**

$$\frac{5 \times (966.069 + 212) + (200 \times 40)}{5 + 200} = 67.75°, \text{ nearly. Ans.}$$

(845) See Art. **1386.**

(*a*) Because the expansion of liquids is best adapted for measurement.

(*b*) Mercury and alcohol. Mercury is used in thermometers which measure high temperatures, and alcohol in those which measure low temperatures.

(846) See Arts. **1400** and **1401.**

(847) (See rule, Art. **1422.**) From Table 55, Art. **1423,** the heat contained in 1 cu. ft. at 140° is 2.2013 B. T. U.

Applying rule, Art. **1422,**

$$\frac{300 \times (140 - 60) \times 2.2013}{140} = 377.3657 \text{ B. T. U. Ans.}$$

(848) See example and rule, Art. **1433.**

Applying the rule,

$$V = 8.02\sqrt{\frac{90\,(300 - 20)}{460 + 20}} = 58.11 \text{ ft. per sec. Ans.}$$

(849) See Art. **1444.**

(850) (See Art. **1451.**) The flow is restricted. (See Fig. 554.)

(851) (*a*) See Arts. **1469** and **1470.**

(*b*) By reversing the vane *v* and so causing the mouth *b* to face the wind.

(852) See Art. **1341.**

(*a*) By the effects it produces.

(*b*) The British thermal unit, the amount of heat required to raise the temperature of 1 pound of water 1° F.

(*c*) Since 1 B. T. U. will raise 1 lb. of water 1°, 6 B. T. U. will raise 6 lb. of water 1°, and as 6 lb. of water must be heated from 50° to 60°, i. e., 10°, it follows that the quantity of heat required is $10 \times 6 = 60$ B. T. U. Ans.

(853) Using rule, Art. **1424,**

$$V_1 = \frac{100\,(460 + 160)}{460 + 0} = 134.8 \text{ cu. ft. Ans.}$$

(854) (See rule, Art. **1479.**) Weight of a cubic foot of aqueous vapor at 35° (see Table 57) is .000325. Weight of 1 cu. ft. at 75° is .00135. Hence, relative humidity $= .000325 \div .00135 = .2407$, or 24.07 per cent. Ans.

(855) (See Art. **1475.**) Water will condense on the inside of the jar when it is cooled below 80°.

(856) See Arts. **1402** and **1403.**

(857) See rule and example, Art. **1423.**

$$W = \frac{2.702 \times 14.7}{460 + 300} = .05226.$$

This is the weight of 1 cu. ft.; consequently, $.05226 \times 100 = 5.226$ lb. = total weight. Ans.

(858) See Arts. **1435** to **1438.**

(859) (See Art. **1479.**) In the zone in which the people breathe. The humidity near the ceiling is usually too low, and near the floor too high, to be accurate. This is due to differences in temperature.

(860) See Fig. 555, Art. **1451.**

(861) See Art. **1478.**

(862) (*a*) See Art. **1343.**

(*b*) See example, Art. **1344.**

SOLUTION.—$500 : x :: 10^2 : 4^2$, or $x = 80°$. Ans.

(863) See example, Art. **1360,** and Table 51 Art. **1359.**

$$\text{Comparative volumes} \begin{cases} \text{at } 200° = 1.03889 \\ \text{at } \ \ 46° = \underline{1.00000} \end{cases}$$

$$\text{Difference} = \ \ .03889$$

Multiplying original volume by this difference, we have

$$560 \times .03889 = 21.77840 \text{ cu. ft.}$$

(864) (See Art. **1376.**) Specific heat of steam is .4805; consequently, $100 \times 10 \times .4805 = 480.5$ B. T. U. required. Ans.

(865) See Art. **1410.**

(*a*) 460° below zero on Fahrenheit scale.

(*b*) It is inferred that all vibratory motion of the molecules would cease at this temperature.

(866) See Arts. **1405** to **1407.**

(867) (See second example, Art. **1423.**) Weight of 1 cu. ft. of air at zero = .08635. Hence, applying rule, Art. **1365,** the number of B. T. U. required to heat 1,000 cu. ft. from 0° to 160° is

$$U = .23751 \times .08635 \times 160 \times 1,000 = 3,281.438 \text{ B. T. U.} \quad \text{Ans.}$$

(868) (See Arts. **1438** and **1439.**) The dial in the cut reads 2,118 feet, and, since we held the anemometer in the current until the dial read 3,078 at the expiration of 2 minutes, it follows that in 2 minutes the velocity was 3,078 − 2,118 = 960 feet, or $\frac{960}{2} = 480$ feet per minute, or $\frac{480}{60} = 8$ feet per second. Ans.

(869) See Art. **1446.**

(870) See Arts. **1452** to **1454.**

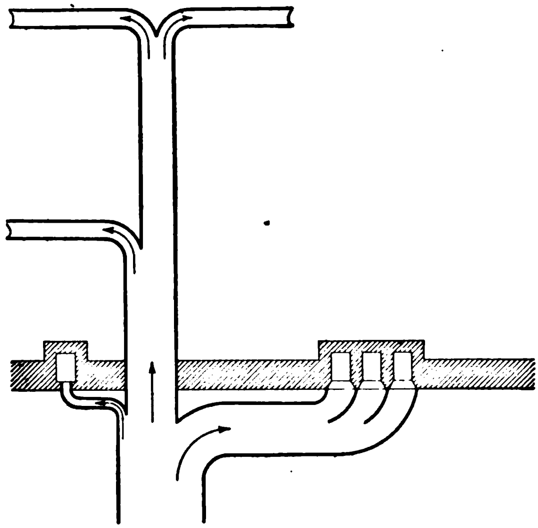


FIG. 25.

(871) (See Art. **1473.**) In the form of a gas.

(872) (See Art. **1484.**) The six factors here given.

(873) (*a*) See Art. **1480.**

(*b*) (See Art. **1480.**) 50 to 70 per cent.

(874) (See column 4 of table of Properties of Saturated Steam.) Latent heat of vaporization is 895.108; consequently, $895.108 \times 20 = 17{,}902.16$ B. T. U. Ans.

(875) See Art. **1410;** also example, Arts. **1391** to **1393.**

(*a*) $75 + 460$ (absolute temperature) $= 535°$ F.

(*b*) $273\frac{1}{3} - 20 = 253\frac{1}{3}°$ C.

(876) See Arts. **1408** and **1409.**

(877) See rule, Art. **1424.**

$$V_1 = \frac{1{,}000 \times 460}{460 + 160} = 741.93 \text{ cu. ft.} \quad \text{Ans.}$$

(878) See Art. **1440.**

(879) (See Art. **1447.**) Use easy curves; guard against use of square elbows, as at Fig. 549.

(880) (See Art. **1456.**) Round in section.

(881) See Art. **1474.**

(882) (See Art. **1347.**) The radiant heat is reflected from the polished silver surface to a greater extent than from a plain iron surface, and, less heat being absorbed by the silver body, it consequently requires a longer time to attain a given temperature.

PRINCIPLES OF HEATING AND VENTILATION.

(QUESTIONS 883–962.)

(883) (See Art. **1502.**) The temperature of ignition is increased by reducing the pressure of the compound, and *vice versa*.

(884) (See Table 59, Art. **1521.**) Volume required is 18 cubic feet for each thousand pounds, and for 25 tons the volume is

$$25 \times 18 \times 2 = 900 \text{ cu. ft.}$$

Length of bin is 18 feet, depth 6 feet, consequently, the width =

$$\frac{900}{18 \times 6} = 8 \text{ ft. } 4 \text{ in., nearly. Ans.}$$

(885) (See Art. **1534.**) (*a*) See explanation of Fig. 582.

(*b*) No. The water will absorb heat just as quickly as the metal can take it in, and as quickly as the heat is conducted through the metal. If extended surfaces were used in this case, the projections would never become hot enough to be of any practical value.

(*c*) If the air is compelled to move rapidly from between the projections, then extended surfaces become useful. If not, it will remain there "dead," and, as it were, clog the radiator.

(886) (See Fig. 593, Art. **1543.**) It is called positive circulating because the steam can not possibly flow directly from the inlet to the outlet opening and leave air locked in the radiator. It must flow through each tube of the radiator and thereby push all air out ahead of it before it reaches the outlet opening, or air vent.

(887) (See Table 64, Art. **1558.**) With a velocity of 20 feet per second, the air will receive from the heater 9 B. T. U. per square foot of heating surface per hour per degree difference. Consequently, each square foot of surface will emit

$$9\,(210 - 60) = 1{,}350 \text{ B. T. U. per hour.}$$

Since there are 3,000 square feet in the heater, the total emission per hour =

$$3{,}000 \times 1{,}350 = 4{,}050{,}000 \text{ B. T. U. Ans.}$$

(888) (See Art. **1570.**) Heat lost from room = 1,000,000 B. T. U. per hour. Heat given off by audience = 1,000 × 400 = 400,000 B. T. U. per hour. Heat given off by the gas lamps = 250 × 2,000 = 500,000. Total emission from lamps and audience = 500,000 + 400,000 = 900,000 B. T. U. per hour. Difference = 1,000,000 − 900,000 = 100,000 B. T. U. per hour. Ans.

(889) (See Art. **1605.**) (*a*) To operate the dampers of a hot-air furnace and thus control combustion.

(*b*) To operate mixing valves and thus control temperature of room.

(*c*) To operate the radiator valves and thus control amount of steam admitted to radiator.

NOTE.—The radiator valves must not be "throttled down"; they must be opened full or entirely closed when steam is the heating medium.

(890) (See Arts. **1583** to **1590.**) See, also, Art. **1581.** Main points are (1) a uniform temperature; (2) a uniform degree of purity of the air; (3) a method of avoiding either hot or cold drafts; (4) prevention of loss of heat.

(891) (See Art. **1595,** and Table 67, Art. **1596.**) Velocity is inversely as the sectional area; consequently, the sectional area, or net area, required at the register is $\frac{7}{4} = 1.75$ sq. ft., or 252 sq. in. Referring to the table just mentioned, this would require a register having a diameter of about 22 inches. Ans.

(892) See Arts. **1486** to **1488;** also **1494.**

(893) (See Art. **1506.**) Five conditions are stated here.

(894) (See Art. **1540.**) This is the most positive circulating and most simple in construction which can be devised for the conditions specified.

(895) See Art. **1616.**

(896) (See Art. **1545.**) Slip a sheet-metal partition into the tube as shown in Fig. 594.

(897) The heat emitted from each square foot of the pipe surface to air having a velocity of 14 feet per second = (see Table 64, Art. **1558**) 7.5 B. T. U. per hour per degree difference. Consequently, each square foot will emit, on an average,

$$7.5 \times 220 = 1,650 \text{ B. T. U. per hour.}$$

The size of the heater then will be

$$\frac{5,000,000}{1,650} = 3,030 \text{ sq. ft.}$$

or $3,030 \times 3 = 9,090$ feet of 1-inch pipe. Ans.

(898) Applying rule, Art. **1571,** we have volume of air $= \dfrac{275,000 \times 58}{120 - 70} = 319,000$ cu. ft. per hour. Ans.

(899) See Art. **1606.**

(900) (See Fig. 609, Art. **1586.**) The best plan is simply to place a register in the vent flue and near the ceiling of the room as shown in this figure, to provide for summer ventilation. The lower register *b* will be used for winter ventilation only. These registers must both be provided with valves, so that when one is open the other may be closed.

(901) See Art. **1597.**

(902) See Arts. **1490** and **1491.**

(903) (*a*) (See Art. **1507.**) On the surface only.

P. V.—15

(*b*) Same page. Difference in time required for the combustion. If each molecule of the combustible matter is surrounded with sufficient oxygen for its complete combustion, then an explosion, or instantaneous combustion, will take place when the matter is ignited. In the case of coal and other fuel, only the surface absorbs oxygen from the air, and the combustion then is comparatively slow.

(904.) (See Arts. **1522** and **1523.**) (*a*) High temperature permanently expands and distorts the cast-iron grate bars.

(*b*) (1) $\frac{3}{8}$-inch to $\frac{1}{2}$-inch air spaces for anthracite.

(2) $\frac{5}{8}$-inch to $\frac{3}{4}$-inch air spaces for bituminous coals.

(*c*) Water bars are commonly used.

(905) (See Art. **1617.**) Make the fans both the same capacity and connect both on to the same countershaft.

If the pressure of the blast from each fan is not equal, air will flow back through the fan which exerts least pressure, and escape.

(906) See Arts. **1548** and **1549.**

(907) (See Baldwin's rule, Art. **1561**; see, also, Art. **1562.**) Glass surface =

$$6 \times 3 \times 4 = 72 \text{ sq. ft.}$$

Exposed wall surface reduced to glass equivalent =

$$\frac{10\,(35 + 30) - 72}{10} = 57.8 \text{ sq. ft.}$$

Cooling surfaces to be calculated against =

$$57.8 + 72 = 129.8 \text{ sq. ft.} = s.$$

By substituting in the formula we have,

$$S = \frac{70 + 10}{227 - 70} \times 129.8 = 66 \text{ sq. ft., nearly.}$$

To this we add 25%, or 16.5 square feet, for air-leakage, which gives us

$$66 + 16.5 = 82.5 \text{ sq. ft.}$$

Then we add 20% (see Art. **1563**), or 16.5 square feet, for wind exposure, which means that the correct size of the radiators is

$$82.5 + 16.5, \text{ or } 99 \text{ sq. ft.}$$

If this is divided into two radiators, they will be as follows:

$$\left.\begin{array}{l} a = 66 \text{ sq. ft.} \\ b = 33 \text{ sq. ft.} \end{array}\right\} \text{Ans.}$$

(908) Applying rule, Art. **1572,** we find the temperature $= \frac{275,000 \times 58}{319,000} + 70 = 120°$. Ans.

(909) (See Art. **1606.**) By the use of a diaphragm motor, as shown in Fig. 616. Oil should be used as the medium which conveys power from the thermostat to the damper motor.

(910) (See Art. **1587.**) The air in the room which is in contact with the windows or other cold surfaces falls to the floor, and a local circulation naturally is formed in the direction of the arrows in Fig. 611. Set the radiator at *d*, for reasons given in Art. **1587.**

(911) See Art. **1598.**

(912) See Arts. **1492** and **1493.**

(913) See rule and example in Art. **1508.**

$B = (145 \times 77 + 620 \times 5) \times 75 = 1,069,875$ B. T. U. Ans.

(914) (See Art. **1524.**) This grate lessens the labor in cleaning the fires. Also permits the fires to be cleaned without opening the furnace doors.

(915) See Art. **1535.**

$\sqrt{180} : \sqrt{560} :: 3.5 : x = 6$ B. T. U., nearly. Ans.

(916) (See Art. **1547.**) The loops of a steam radiator of this form are connected at bottom only, and a hot-water radiator at top and bottom. The steam circulates through this loop on the same principle that it does in the Nason

tube or Bundy loop. The air is extracted by an air vent or other small valve placed on the loop opposite the steam inlet, as at *d* in Fig. 593, Art. **1544.**

(917) No. See reasons given in Arts. **1561** to **1564.**

(918) See Art. **1573.**

(919) (*a*) (See example, Art. **1609.**) Total weight of column of air 65 feet high, reduced by amount equal to .2-inch water column = 1.0417 pounds per square foot.

The air when heated must weigh

$$\frac{65 \times .08635 - 1.0417}{65} = .0703 \text{ pound per cu. ft.}$$

Referring to Table 55, Art. **1423,** we find that this weight corresponds to a temperature of about 100°. The amount of heat required will then be (see rule, Art. **1365**) $15{,}000 \times .08635 \times .2375 \times 100 = 30{,}762$ B. T. U.

(*b*) The mechanical power required will be (see Art. **1609**)

$$15{,}000 \times 1.0417 = 15{,}625.5 \text{ foot-pounds per minute.}$$

Converting this into heat units, we have

$$\frac{15{,}625.5}{778} = 20 \text{ B. T. U., nearly. Ans.}$$

(920) No (see Art. **1588**).

(921) See Arts. **1598** and **1599.**

(922) See Art. **1494.**

(923) (See rule, Art. **1509.**) Heat of combustion is 14,265 B. T. U.; consequently,

$$23 \times \frac{14{,}265}{966} = 339.7 \text{ pounds, nearly. Ans.}$$

(924) See rule, Art. **1525.**

Weight of column of air at 65° F. (see Table 55, Art. **1423**) $= 95 \times .0756 = 7.182$ pounds. Rate of combustion (see Table 58, Art. **1513**) shows that 20.2 pounds of air

will be used for each pound of coal. During combustion this takes up 1 pound carbon, and the weight, consequently, becomes 21.2 pounds, say 21 pounds. In this case the proportion is then 21 to 20, or an excess of 5 per cent. The weight of 95 cu. ft. of chimney gases at 65° is, therefore, 7.182 + 5 per cent. = 7.541 pounds, but at a temperature of 250° (710°, absolute) the weight is diminished to

$$7.541 \times \frac{65 + 460}{710} = 5.58, \text{ nearly.}$$

Draft pressure will then be $7.182 - 5.58 = 1.6$ pounds per sq. ft., or $12 \times \frac{1.6}{62} = .3$ inch of water column, nearly. Ans.

(925) (*a*) (See Art. **1536.**) The lower parts of the radiators, or coils, are most efficient.

(*b*) (See Art. **1536.**) The greatest efficiency is obtained by arranging the surfaces, as shown in Fig. 585. This should always be done when it is practicable.

(926) (*a*) See Art. **1552,** and Fig. 602.

(*b*) To cause all parts of the air current which passes through the heater horizontally to come in direct contact with the tubes. It prevents a cold current from blowing through the heater.

(*c*) They are usually employed in the "blower system," and the air current is generally obtained by the use of a fan.

(927) (See Art. **1564.**) (*a*) Area of direct-indirect radiator surface may be found by adding 25% to the area of direct radiators required for the same room; consequently,

$$\left.\begin{array}{l}\text{Size of direct-indirect radiator for room } A = 80 + 20 = 100 \text{ sq. ft.}\\ \text{Size of direct-indirect radiator for room } B = 60 + 15 = 75 \text{ sq. ft.}\\ \text{Size of direct-indirect radiator for room } C = 48 + 12 = 60 \text{ sq. ft.}\end{array}\right\} \text{Ans.}$$

(*b*) Area of indirect radiator may be found in the same way by adding 50%, as follows:

$$\left.\begin{array}{l}\text{Size of indirect radiator for room } A = 80 + 40 = 120 \text{ sq. ft.}\\ \text{Size of indirect radiator for room } B = 60 + 30 = 90 \text{ sq. ft.}\\ \text{Size of indirect radiator for room } C = 48 + 24 = 72 \text{ sq. ft.}\end{array}\right\} \text{Ans.}$$

(928) See Art. **1575.**

(929) See Arts. **1611** and **1612.**

(930) No; it is bad practice. (See Art. **1591.**)

(931) See Art. **1600.**

(932) (See Art. **1496.**) (*a*) Nitrogen takes no active part and is not changed by the process of combustion of fuel.

(*b*) Products of combustion of carbon are chiefly CO or CO_2; other products are due to impurities in the fuel. Products of combustion of hydrogen are H_2O, or water.

(933) (See Art. **1511.**) 24 pounds of air are usually estimated to burn 1 pound of coal with natural draft; consequently, the volume of air required equals $24 \times 35 \times 13.5 = 11,340$ cu. ft., nearly. Ans.

(934) (See Art. **1529.**) (*a*) Chiefly by the actual contact of the air with the heating surfaces of the radiator. If the walls or furniture, etc., absorb sufficient radiant heat from the radiator to raise their temperature above that of the air in the room, they also act as heating agents. If the air in the room is pure (free from dust or particles of solid matter), radiant heat will not affect its temperature.

(*b*) If air currents did not exist around and in between the heating surfaces of a radiator, the transmission of heat from the radiator to the air in the room would be too slow to be of any practical value. A film or layer of hot "dead air" surrounds a radiator. The more rapid the currents, and the closer they impinge upon the heating surfaces, the thinner will be the film of dead air, and the more rapid will be the transmission of heat from the radiator to the air in the room.

(935) (See Art. **1536,** and Fig. 592.) The inner pipes are very inefficient, because they are surrounded by hot pipes, and the air which comes in contact with them is usually quite warm. Their radiant heat is absorbed by the outer pipes.

Box coils are, consequently, seldom used as radiators, ex-

cept in cases where the air is forced through by a fan or other means; then they are usually called "heaters," not radiators.

(936) (See Art. **1553.**) The radiator is placed within the room which is to be heated, and fresh air from the outer atmosphere is allowed to flow through between the heating surfaces and into the room. (See Fig. 603.)

(937) See Art. **1565.**

(938) (See Art. **1579.**) A small flue must be attached to each gas or oil stove to carry off the products of combustion to the outer atmosphere.

(939) See Art. **1613.**

(940) (See Art. **1592.**) Hang the coils overhead in a horizontal manner, as in Fig. 585, Art. **1536.**

(941) (See Art. **1601.**) By adjusting the inlet valve, thus controlling the amount of hot water which flows through it; or by regulating combustion at the furnace.

(942) (See Arts. **1496** to **1499.**) (*a*) 11.6 pounds of air are required for the complete combustion of 1 pound of carbon; consequently,

$$11.6 \times 21 = 243.6 \text{ lb. Ans.}$$

(*b*) See Art. **1499.** One-half the quantity of air is required; consequently,

$$\frac{243.6}{2} = 121.8 \text{ lb. of air. Ans.}$$

(943) (See Table 58, Art. **1513.**) One ton equals 2,000 lb. The amount of air required for the hot-water boiler will be

$$304.85 \times 2{,}000 = 609{,}700 \text{ cu. ft. Ans.}$$

The amount of air required for the low-pressure steam boiler (see same table) equals

$$265.45 \times 2{,}000 = 530{,}900 \text{ cu. ft. Ans.}$$

The amount required for the power boiler equals

$$170.83 \times 2{,}000 = 341{,}660 \text{ cu. ft. Ans.}$$

(944) (*a*) See Art. **1531.**

(*b*) See Art. **1532.**

(945) (See Art. **1537.**) (*a*) A radiator provided with vertical flues which pass through between the internal heating surfaces. The tops and bottoms of the flues are open to the atmosphere.

(*b*) The air in the flues, being rarefied with the heat, simply flows up and out of the top, cold air entering at the bottom to replace it. An upward current of air is thus obtained in each flue, and the hot air is rapidly discharged into the room.

(946) (See Table 61, Art. **1555.**) (*a*) The room A is to be heated with a radiator having single tubes 40 inches high. According to the table, each square foot will emit

$$1.85\,(220 - 70) = 277.5 \text{ B. T. U. per hour.}$$

The size of radiator, then, will be

$$\frac{30,525}{277.5} = 110 \text{ sq. ft.} \quad \text{Ans.}$$

(*b*) In like manner, each square foot of surface in the low radiator in room B will emit

$$2.53\,(220 - 70) = 379.5 \text{ B. T. U. per hour,}$$

and the size of this radiator, then, will be

$$\frac{30,525}{379.5} = 80.5 \text{ sq. ft., nearly.} \quad \text{Ans.}$$

(947) (See Table 65, Art. **1566.**) Each square foot of an 8-inch brick wall conducts $.46 \times 70 = 32.2$ B. T. U. from the air in the room to the outer atmosphere in one hour. Consequently, the total loss from the brick wall will be $875 \times 32.2 = 28,175$ B. T. U. per hour. Excess of loss $= 28,175 - 6,125 = 22,050$ B. T. U. per hour. Ans.

(948) See Art. **1580.**

(949) See Art. **1614.**

(950) (See Table 66, Art. **1594.**) Difference in temperature in this case is $115° + 10° = 125°$. Consequently, referring to "the 10 feet in height" column of the table, the volume delivered in one minute will be 384 cu. ft., which in one hour will equal $384 \times 60 = 23,040$ cu. ft. Ans.

(951) See Art. **1601.**

(952) (*a*) (See Art. **1499.**) One pound of carbon requires 152 cu. ft. of air for complete combustion; consequently, $135 \times 152 = 20,520$ cu. ft. Ans.

(*b*) (See Art. **1499.**) $CO_2 + N$.

(953) (See Arts. **1520** and **1521.**) The coal should be stored separate in the bin. To prevent waste they should be used separately. Guard against mixing them.

(954) (See Art. **1532.**) (*a*) Since *A*, whose rate of emission is 100, emits 15,000 B. T. U. in one hour, it follows that *B*, whose rate of emission is 106, will emit

$$15,000 \times \frac{106}{100} = 15,900 \text{ B. T. U. per hour. Ans.}$$

(*b*) By the same reasoning, *C* will emit

$$15,000 \times \frac{90}{100} = 13,500 \text{ B. T. U. Ans.}$$

(955) (*a*) A "miter coil" (see Art. **1541**) should be used.

(*b*) The "spring pieces" provide for expansion.

(*c*) The coils should be secured to the walls by hook plates and wooden wall strips. The strips are nailed to wooden plugs which are driven into the joints of the brickwork. The hook plates are screwed on the strips. The pipes are thus kept about $1\frac{1}{2}$ inches from the wall, so that a circulation of air can be obtained behind the pipes.

(956) (See Table 63, Art. **1558.**) (*a*) Emission of heat from radiator per square foot of surface per hour per degree difference in temperature = 1.70 B. T. U.; conse-

quently, amount of heat given off per hour by each square foot of heating surface =

$$1.70\,(220 - 70) = 255 \text{ B. T. U.}$$

Size of radiator, then, will be

$$\frac{31,875}{255} = 125 \text{ sq. ft.} \quad \text{Ans.}$$

(*b*) In like manner, the amount of heat given off per hour by each square foot of heating surface in this radiator =

$$2.67\,(220 - 70) = 400.5 \text{ B. T. U.}$$

Consequently, size of radiator =

$$\frac{31,875}{400.5} = 79.58, \text{ say } 80 \text{ sq. ft., nearly.} \quad \text{Ans.}$$

(957) (See Art. **1567.**) (*a*) 10 per cent.

(*b*) 50 per cent.

(958) See Art. **1582.**

(959) See Art. **1615.**

(960) (See Art. **1594.**) (*a*) Not more than 4 feet per second.

(*b*) By enlarging the outlet orifice.

(961) See Arts. **1603** and **1604.**

(962) See rule, Art. **1500.**

$$1.52\ (82 + 3 \times 6) \times 121 = 18,392 \text{ lb.} \quad \text{Ans.}$$

STEAM HEATING.

(QUESTIONS 963–1052.)

(963) (See Art. **1619.**) (*a*) A movement of the water over the heating surfaces of the boiler; essentially composed of one or more upward currents and one or more downward currents.

(*b*) (1) A difference in density of the water in different parts of the boiler. (2) The buoyancy of the steam.

(964) (See Art. **1639.**) Use a reenforce ring to strengthen the boiler plates.

(965) (See Art. **1649.**) (*a*) Flues are large and accessible from the doors on the front, and can easily be examined and cleaned out.

(*b*) Circulation is positive in each section, because each section forms a complete loop. (See Fig. 647.) The return manifolds *b* ensure a supply of feed-water to each section independent of the others.

(*c*) The boiler can be easily enlarged by simply adding more sections and grate bars, and lengthening the manifolds to suit.

(966) See Art. **1665.**

(967) See Art. **1686.**

(968) See Example II, Art. **1699.**

Supposing the loop to be full of steam only, the water will rise in the drop pipe $2 \times 2.31 = 4.62$ feet, to balance the stated difference in pressures. For reasons given in Art. **1699,** top of water column will stand $4.62 + 10 = 14.62$ feet above foot of riser. Additional height will be 14.62

$\div 3 = 4.87$ feet, nearly. Final height above boiler water-level becomes $14.62 + 4.87 - 10 = 9.49$ feet, say 10 feet, nearly. Ans.

(969) See Art. **1719,** and Fig. 683.

(970) See Art. **1735,** and Fig. 690.

(971) See rule, Art. **1745.**

$$\sqrt{\frac{4,900}{100} \div .7854} = 8 \text{ inches, nearly. Ans.}$$

(972) (See Art. **1619.**) The water will be lifted away from the heating surface, and the plates are liable to become overheated.

(973) See Art. **1630.**

(974) See Art. **1640.**

(975) (See Art. **1650.**) To remove the water from the drop tubes, a slow fire must be run in the furnace until every drop of water has been evaporated and passed out of the boiler to the atmosphere in the form of steam. Care must be taken not to burn the drop tubes.

(976) See Art. **1666.**

(977) (See Art. **1687.**) A stop-valve should *never be used under any circumstances.* Open communication must always exist between the safety valve and the boiler.

(978) (See Art. **1701.**) The height of a column of cold water required to resist a pressure of $5 - 2 = 3$ lb. is (see Art. **549**) $3 \div .434 = 7$ ft., nearly. But, as the water in the siphon will be hot, say 212°, instead of cold, the actual height of the column required will be (see column 2, Table 51, Art. **1359**) $7 \times 1.0444 = 7.31$ ft., or, 7 ft. $3\frac{3}{4}$ inches, nearly. Ans.

(979) See Art. **1722,** and Fig. 686.

(980) (See Art. **1738.**) Pitch at least $\frac{1}{2}$ inch in 10 feet.

(981) See Arts. **1747** to **1750.**

(982) See Arts. **1621** and **1622.**

(983) (*a*) See Art. **1631.**

(*b*) Same page. No; because of unequal expansion and contraction of the rods and the shells.

(984) (*a*) See Art. **1641.**

(*b*) By four lugs riveted on the shell.

(*c*) The lower half of the shell, because the furnace gases are hottest as they travel over this part. Dust and soot can not gather on it.

(985) (See Art. **1651.**) A motor horsepower is 33,000 foot-pounds of work done in one minute. A boiler horsepower equals 33,330 B. T. U. of heat per hour transmitted from the fuel to the water in the boiler.

(986) See Arts. **1667** and **1668.**

(987) See Arts. **1688** and **1689.**

(988) See Art. **1702.**

(989) (See Art. **1727.**) (*a*) To return water of condensation back to the boiler.

(*b*) (See Art. **1727.**) Clean and pure feed-water is obtained, and much heat is saved, as the water of condensation is quite hot.

(990) (See Art. **1739,** and Fig. 693.) Vertical offsets or relays must be used. The relief pipes, as at *a* in Fig. 693, bleed the steam main into the return main.

(991) (See Art. **1750.**) Use ventilated floor and ceiling plates.

(992) (See Art. **1623.**) The drop tube should have an inner tube, as in Fig. 625, to supply water to the outer chamber and thereby ensure uninterrupted circulation.

(993) (*a*) (See Arts. **1631** to **1633.**) Diagonal or gusset stays should be used.

(*b*) (See Art. **1632.**) Not more than 30°.

(994) See Art. **1642.**

(995) (See Art. **1654.**) About 30 pounds of steam are required per hour per horsepower; consequently, the boiler must generate $10 \times 30 = 300$ lb. of steam per hour, nearly. Ans.

(996) See Art. **1669.**

(997) See Art. **1690.**

(998) See Art. **1703.**

(999) No. See Art. **1727.**

(1000) (See Art. **1740.**) Take connection from top of main for one-pipe work.

(1001) See Art. **1754,** and Fig. 703.

(1002) (See Art. **1624.**) (*a*) May be used to advantage in the water legs of boilers of the locomotive type.

(*b*) (See Fig. 641.) *P* is a baffle plate which compels the hot gases to travel over the outer part of the boiler and give up more heat to the water than would be obtained if the gases flowed directly into the chimney.

(1003) (See Art. **1634.**) Are commonly used over the crown sheets of boilers of the locomotive type.

(1004) (See Art. **1643.**) Fig. 639 is the best.

(1005) (See Art. **1657.**) Since the boiler must make steam readily without a rapid rate of combustion (see note in question), we should use the largest numbers given in Table 69, Art. **1657.** Consequently,

(*a*) requires $18 \times 15 = 270$ sq. ft. of heating surface. Ans.

(*b*) requires $12 \times 15 = 180$ sq. ft. of heating surface. Ans.

(*c*) requires $14 \times 15 = 210$ sq. ft. of heating surface. Ans.

(1006) See Art. **1671.**

(1007) See Art. **1692.**

(1008) See Art. **1704,** and Fig. 668.

(1009) See Art. **1728.**

(1010) See Art. **1741,** and Fig. 697.

(1011) See Art. **1755.**

(1012) (See Art. **1625.**) If return tubes are not used, and if the water can not otherwise have free and easy access to the heating surfaces (see Art. **1619**), the water will be forced away from the surfaces, and they, consequently, may become overheated and burned. A spasmodic production of steam will, no doubt, ensue.

(1013) See Art. **1637.**

(1014) See Art. **1644.**

(1015) See Art. **1658.**

(*a*) $45 \times .5 = 22.5$ sq. ft. grate surface. Ans.

(*b*) $45 \times .3 = 13.5$ sq. ft. grate surface. Ans.

(*c*) $45 \times .4 = 18$ sq. ft. grate surface. Ans.

(1016) See Art. **1673.**

(1017) See Art. **1693.**

(1018) See Art. **1708.**

(1019) See Art. **1729.**

(1020) See Art. **1741,** and Fig. 700.

(1021) See Arts. **1756** and **1757.**

(1022) (See Art. **1626.**) Rate of transmission is proportional to the difference between the temperature of the water and the hot gases. It decreases as the metal is increased in thickness, and increases with the cleanliness of

the surfaces. It increases with the angle at which the gases impinge upon the surfaces. (See Art. **1627.**)

(1023) (See Art. **1638.**) (*a*) The seams or joints.

(*b*) Single-lap seam is 60 to 66 per cent. as strong as the plate. Double-riveted lap seams are about 70 to 77 per cent. as strong as the plate.

(1024) See Art. **1645.**

(1025) See Arts. **1659** to **1661.**

(1026) See Art. **1675.**

(1027) (See Art. **1695.**) Since the water of condensation is hot, it follows that the pump must be set low enough for the water to fall into the cylinders by gravity.

(1028) See Art. **1710,** and Fig. 672.

(1029) (See Art. **1732.**) The condensed water returns to the boiler against the flow of the steam.

(1030) See Art. **1742.**

(1031) See Art. **1758,** and Fig. 705.

(1032) See Art. **1627.**

(1033) (See Art. **1638.**) (*a*) Longitudinal seams.

(*b*) Because the strains in them are twice as great as in the transverse seams.

(1034) See Art. **1646.**

(1035) (See Art. **1662.**) (*a*) The carbonate will be precipitated in the boiler when the water is heated, and may be blown off.

(*b*) The sulphate of lime forms a hard scale on the iron plates and can not be blown off.

(1036) See Art. **1684.**

(1037) (See Art. **1696.**) (*a*) See description of Fig. 661 or Fig. 662; either will do.

(*b*) Set above level of boiler.

(*c*) A current of cold air will condense the steam in the globe quickly, and the trap will operate more rapidly than if set in a medium of quiet or warm air.

(1038) See Art. **1713,** and Fig. 675.

(1039) See Art. **1733.**

(1040) See Art. **1743.**

SOLUTION.—$29 \times (5 - 3.5) = 43.5$ inches, or 3 ft. $7\frac{1}{2}$ in. Ans.

(1041) See Arts. **1760** and **1761,** and Fig. 706.

(1042) (*a*) (See Art. **1628.**) The hot gases will pass into the chimney at too high a temperature, and heat will consequently be lost.

(*b*) (See Art. **1628.**) The tubes will not be properly filled with water. It will be displaced by steam.

(1043) (See Art. **1638.**) (*a*) No. They are liable to become burned and leaky.

(*b*) Longitudinal joints located above the water-line; consequently, free from the action of the fire. The tube ends should be expanded into their fittings.

(1044) See Art. **1648.**

(1045) (See Art. **1663.**) (*a*) Prevents transmission of heat from the fuel to the water.

(*b*) Clogs gauges, allows plates to overheat and blister, conceals defects, etc.

(*c*) See Art. **1664.**

(1046) See Art. **1685.**

(1047) (*a*) See Art. **1698.**

(*b*) See Art. **1698.**

(1048) (See Art. **1717.**) (*a*) By an expansion joint, same as shown in Fig. 682, because the line is straight.

(*b*) (See Art. **1718.**) $1\frac{1}{2} \times 3 = 4\frac{1}{2}$ in. must be allowed for expansion.

(*c*) See description of Fig. 682.

(1049) See Art. **1734.**

(1050) (See tables of sizes of pipe required, Art. **1744.**) (*a*) Size of pipe $1\frac{1}{2}$ inches. Ans.

(*b*) Size of steam pipe $1\frac{1}{4}$ inches, return pipe 1 inch. Ans.

(*c*) Size of steam pipe 2 inches, return pipe 1 inch. Ans.

(1051) See Art. **1763.**

(1052) (*a*) (See Art. **1629.**) Flat surfaces.

(*b*) (See Art. **1629.**) By the use of staybolts or braces.

HOT-WATER HEATING.

(QUESTIONS 1053–1116.)

(1053) (See Art. **1773.**) Steam draft regulators operate by changes in the steam pressure. Hot-water regulators operate by difference in temperature.

(1054) (See Art. **1780.**) (*a*) By a glass water gauge. (*b*) By gauge-cocks or "try" cocks.

(1055) (See Art. **1791.**) They are required only to shut off a current.

(1056) (See Art. **1800.**) From under side of main, to prevent air-lock in the branches.

(1057) (See Art. **1808.**) The radiators on the upper floors will receive hot water, but those on the lower floors will have a much colder supply. This is due to the fact that the cooled water discharged from the upper radiators will mix with the descending hot water and reduce its temperature considerably.

(1058) (*a*) (See Art. **1813.**) (*b*) To form equal resistance to the flow through each circuit.

(1059) (See Art. **1817.**) Allowing 70 diameters for each elbow and **T**, the length to be added would be $\frac{10 + 4 \times 70 \times 2}{12} = 163$ ft. 4 in. Ans.

(1060) (See Art. **1824.**) $220 + 50\% = 220 + 110 = 330$ sq. ft. = equivalent in direct radiation. Referring to Table 73, Art. **1820,** it will be seen that a 3-inch pipe is required.

NOTE.—A smaller pipe will produce a greater fall in temperature.

(1061) See Art. **1834.** Exposed glass is 800 square feet. $\frac{200 \text{ sq. ft. wall surface}}{4} = 50$ sq. ft. glass surface.

Total heat-emitting glass surface and equivalent in wall surface $= 800 + 50 = 850$ sq. ft. Since the greenhouse is exposed to winds, we will assume a loss of 60 B. T. U. per hour per square foot of glass; consequently, total loss of heat per hour will be about $850 \times 60 = 51{,}000$ B. T. U.

(1062) (*a*) (See Art. **1765,** and Fig. 707.) Insert flue tubes through the steam space. (*b*) (See Art. **1769.**) Keep the top row of tubes down low enough so as not to obstruct outlet of hot water; also keep bottom row high enough so as not to obstruct inlet of water.

(1063) (See Art. **1773.**) Connect a return pipe from regulator into bottom of boiler, so as to obtain a special circuit for regulator.

(1064) (See Art. **1795.**) A small hole, or by-pass, should be provided in the valve to allow slight circulation through the radiator.

(1065) See Art. **1796.**

(1066) (See Art. **1801.**) Flow connection on top and return on bottom, the flow supply being taken from the current first. (See Fig. 729.)

(1067) (*a*) See Arts. **1809** and **1810.** (*b*) The

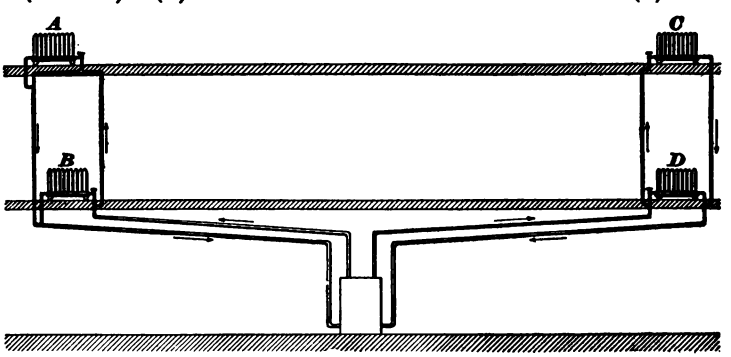


FIG. 26.

accompanying Fig. 26 shows the underlying principle. The methods of running the pipes may vary.

(1068) See Art. **1814.** (*a*) Velocity will be 1 foot per second in return pipe, same as in the flow pipe. (*b*) The velocity is inversely proportional to the squares of the diameters; consequently, $1 \times \frac{2^2}{1.5^2} = 1.7778$ ft. per second.

(1069) (See Table 73, Art. **1820.**) According to this table, a 6-inch pipe will be large enough.

(1070) By reference to Tables 73 and 74, the pipes will be proportioned as in Fig. 27.

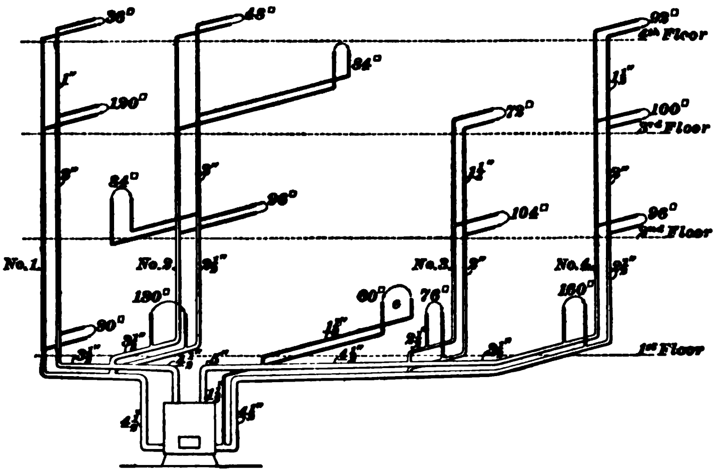


FIG. 27.

(1071) (See Table 76, Art. **1835.**) Total amount of glass surface and its equivalent equals $2,400 + \frac{600}{4} = 2,550$ sq. ft. According to the table of ratios, $\frac{2,550}{3.5} = 730$ sq. ft., nearly.

(1072) No. (See Art. **1766.**)

(1073) See description of Fig. 713, Art. **1774.**

(1074) (See Art. **1781.**) Use an arrangement similar to Fig. 716.

(1075) See Art. **1797.**

(1076) When water is run into the system, air will accumulate in the return pipes under the left-hand bench; consequently, the water will not circulate through the greenhouse. To remedy the defect, an air-vent pipe should be taken from the highest point of the air-lock and led up into the main *a*, or over and into the top of the expansion tank. (See Art. **1802.**)

(1077) See Art. **1810.**

(1078) (See Table 72, Art. **1814.**) (*a*) Difference in temperature $= 160 - 140 = 20°$, which, for a 15-foot high circuit, corresponds to a velocity of 1.91 feet per second. Ans.

(*b*) By the same method, $200 - 160 = 40° =$ difference in temperature according to the table; the velocity will be 6.03 feet per second. Ans.

(1079) (See Table 73, Art. **1820.**) With a circuit of 300 feet, a 4-inch main will supply 390 square feet direct radiation on first floor, or (see table of factors in Art. **1816**) $390 \times 1.70 = 663$ square feet on third floor, or 100 square feet on first floor, and $290 \times 1.70 = 493$ square feet on third floor. The extra surface which the pipe will supply on the third floor, then, will be about $493 - 300 = 193$ square feet. Ans.

(1080) (See Art. **1805.**) (*a*) Positive and direct circulation in each circuit. (*b*) Objectionable, chiefly on account of the numerous pipes required.

(1081) See Arts. **1836** to **1838.**

(1082) (See Art. **1766.**) The steam in the rising part of the circuit gives this part a lower mean density, and, consequently, the velocity of circulation is increased.

(1083) (*a*) and (*b*) See Art. **1775.** (*c*) 825 U. S. gallons = 100 cubic feet. See Art. **1775.** Tank capacity should be about $\frac{1}{20}$ of total capacity of apparatus; consequently, $\frac{100}{20} = 5$ cubic feet = tank capacity between the gauges.

(1084) (See Art. **1782.**) Top connections are made especially to allow air in each loop to escape from one air vent on the end loop, and so allow circulation between the loops. Bottom connections allow of water circulation only.

(1085) (See Art. **1797.**) (*a*) They should be so balanced that they will just float up to the seat. If they are too light, the pressure will keep them up. (*b*) Since the valves operate when under low pressure, as on the top floor, and do not operate when subject to high pressure, as on the lower floors, it is evident that the floats are too light, or the pressure too heavy, for the class of valve used.

(1086) See Art. **1803.**

(1087) See Art. **1811.**

(1088) See Art. **1815.** Fall in temperature will be inversely proportional to volume of water passing through, that is, proportional to the velocity, consequently, $40 \times \frac{1}{1.75} = 22.86°$ F., nearly. Ans.

(1089) (See Table 74, Art. **1822.**) (*a*) 2-inch pipe. (*b*) $1\frac{1}{4}$-inch; $1\frac{1}{2}$-inch may be used, if desired. (*c*) 1-inch pipe.

(1090) See Art. **1831.**

(1091) See Art. **1839.**

(1092) (See Art. **1768.**) The former contain but little heat and soon cool off. They are rapid heaters. The latter require a longer time to heat, but when hot also require a long time to cool.

(1093) (See Art. **1776.**) (*a*) An expansion tank in which the fluids are entirely disconnected from the atmosphere. (*b*) Used to compensate for expansion and contraction of the water in the heating apparatus; also, to increase the pressure of the water when it is being heated, thus raising its boiling point. (See table of Properties of Saturated Steam.) (*c*) A safety valve must be attached, and properly adjusted to blow off at a safe pressure. A vacuum valve may also be used, but this is not strictly necessary.

(1094) (See Art. **1785.**) Connect the indirect radiators without valves or any other apparatus to stop circulation.

(1095) (See Art. **1798.**) (*a*) Air and other gases are liberated from the water when it is being heated. Being lighter than water, they simply rise to the highest points. (*b*) After the water has reached the boiling point.

(1096) (See Arts. **1803** and **1804.**) (*a*) Upon the difference between the mean temperature of the water in the ascending and the descending parts of the circuit; also, upon the height of the circuit. (*b*) It is proportional to the height of the circuit.

(1097) (See Art. **1811.**) Since the cold water from the radiators mixes with the hot water in the mains, and the temperature at the end of the main, consequently, is much lower than that of the inlet end, it follows that radiator surface supplied with the cooler water must be increased to correspond with the reduction in temperature.

(1098) (See Art. **1816.**) Factor given in this article is .76; consequently, the size of pipe required is $2 \times .76 = 1.52$, or $1\frac{1}{2}$-inch pipe. Ans.

(1099) (See Art. **1824.**) (*a*) 29 feet in height. (*b*) 30 feet in height. (*c*) 80 feet in height.

(1100) See Arts. **1832** and **1833.**

(1101) See Art. **1840.**

(1102) (See Art. **1769.**) (*a*) Circulation should be as free as possible, and it should be upwards in all parts of the boiler. Local circulation in hot-water boilers is objectionable. (*b*) The flues may be close up to, or even over, the top of the boiler, but in all cases must be easy to clean. (*c*) The flow connections are taken from extreme top of heater, and the return connections entered at the lowest point. Ample waterway must be allowed within the boiler at both top and bottom.

(1103) (*a*) (See Arts. **1775** to **1777.**) (*b*) Open-tank system for reasons of safety.

(1104) (See Art. **1786.**) (*a*) Bends do not retard the flow as much as elbows. (*b*) Ream the pipe ends. (See Fig. 720.)

(1105) (See Art. **1798.**) It will obstruct the flow of water through the pipes by reducing the sectional area of the current.

(1106) (See Art. **1804.**) (*a*) Yes. (*b*) Since the drop pipe *d* is exposed to the atmosphere, it consequently cools off, and the water in it becomes more dense than that in the rising supply. This difference will cause a sluggish circulation through the radiator, which will vary with the height of the circuit and the cooling effect of the air upon the drop pipe.

(1107) (See Art. **1812.**) It tends to furnish a uniform flow at uniform temperatures to all radiators at the same time.

(1108) (See Art. **1816.**) According to the table given in this article, $84 \times 1.70 = 142.8$ square feet. Ans.

(1109) (See Art. **1823.**) (*a*) 1 inch. (*b*) $1\frac{1}{4}$ inches. (*c*) $2\frac{1}{2}$ inches.

(1110) See Art. **1832.**

(1111) See Art. **1840.**

(1112) (See Art. **1772.**) (*a*) Wrought iron or steel having rounded surfaces. Pipe preferred. (*b*) Small volume is desirable, because if an explosion should occur, the effect will be less than that from a large volume of the same water.

(1113) See Arts. **1778** and **1789.**

(1114) (See Art. **1787,** and Fig. 721.) Flush fittings.

(1115) (See Art. **1800.**) Branches should always be taken from top of mains. This will carry off air bubbles in the water.

(1116) See Arts. **1805** and **1806.**

FURNACE HEATING.

(QUESTIONS 1117–1161.)

(1117) (See Arts. **1845** and **1846.**) The belt k gives Fig. 747 a decided advantage over the plain cylinder of Fig. 746. Otherwise the furnaces are about the same.

(1118) (See Arts. **1850** and **1851.**) The heating tubes are continued down nearly to the floor, thus securing a maximum height of hot-air column, which is very favorable to a high velocity of air through the heater. As the air ascends, it flows zigzag between the hot tubes and impinges upon them nearly at right angles. The furnace sits very low, and consequently allows the hot-air pipes to have a good pitch upwards towards the registers. The large dome, or hood, over the furnace allows an uninterrupted flow of hot air to each hot-air leader pipe.

(1119) See Art. **1859.**

(1120) See Art. **1869.**

(1121) See Art. **1875.**

(1122) See Art. **1880.**

(1123) (See Art. **1885.**) $\frac{2}{3}$ of $500 = 334$ sq. in., nearly. Ans.

(1124) (See Art. **1892.**) (*a*) Dampers for controlling the volume of air delivered. (*b*) Butterfly valves or dampers are sufficiently tight for this purpose. They are located in the leaders and near the furnace bonnet.

(1125) (See rule, Art. **1900.**) Take the rule which proportions the pipes to the areas of the cooling surfaces in the rooms.

SOLUTION.— Glass surface 50 sq. ft.
Wall surface 240 = Glass equivalent 60 sq. ft.
Total 110 sq. ft.

Size of pipe for first floor is $110 \times 1.5 = 165 = 14\frac{1}{2}$ in. diam. Ans.
Size of pipe for second floor is $110 \times 1.25 = 137 = 13\frac{1}{4}$ in. diam. Ans.
Size of pipe for third floor is $110 \times 1 = 110 = 11\frac{7}{8}$ in. diam. Ans.

(1126) (See Art. **1843.**) The ratio between grate surface and furnace-heating surface should average 1 to 50; consequently, $6.5 \times 50 = 325$ sq. ft. Ans.

(1127) See Art. **1847.**

(1128) (*a*) (See Art. **1852.**) A combination heater is simply a hot-air furnace fitted with an attachment for heating water or making steam, as the case may require. (*b*) (See Arts. **1852–1854,** and also Art. **1904.**) It is considered good practice to use them only when a few of the rooms to be heated are too far away from the furnace. Long hot-air leader pipes, if nearly level, seldom give good results. Hence, the necessity of combination heaters.

(1129) (See Art. **1859.**) The space should be 8 to 12 inches deep, or more, to prevent overheating the bonnet and choking the air supply.

(1130) See Art. **1870.**

(1131) See Art. **1876.**

(1132) See Art. **1884.**

(1133) See Art. **1886.**

(1134) See Arts. **1894** and **1895.**

(1135) See Art. **1901.**

SOLUTION.—

Diameter of pipe for first floor $=\frac{21,000}{100}=210=16\frac{3}{8}$ in. Ans.

Diameter of pipe for second floor $=\frac{21,000}{125}=168=14\frac{5}{8}$ in. Ans.

Diameter of pipe for third floor $=\frac{21,000}{150}=140=13\frac{3}{8}$ in. Ans.

(1136) (See Art. **1843.**) The gases as they leave the furnace should have a temperature not higher than

$$180^\circ + 100^\circ = 280^\circ \text{ F.} \quad \text{Ans.}$$

(1137) (See Art. **1848.**) (*a*) Close damper *h* and open *i* to form a direct draft; otherwise, the cellar will fill with smoke. (*b*) Open *i″* and close *i*. (*c*) Open *h*. This damper should otherwise remain tightly closed all the time.

(1138) See Art. **1856.**

(1139) See Arts. **1861–1864.**

(1140) No. See Art. **1871.**

(1141) See Art. **1877.**

(1142) See Art. **1885.**

(1143) See Fig. 767.

(1144) Fig. 771 is the best.

(1145) See Art. **1903.**

SOLUTION.—Loss by cooling is 136,000 B. T. U. per hour. Total loss by cooling and ventilation $= 136,000 \times 2.18 =$ 296,480 B. T. U. per hour. Efficiency of the furnace being 50%, it follows that 50% of 13,400, or 6,700 B. T. U. are used for each pound of coal burned; therefore,

(*a*) Amount of coal required to heat the building for a period of 24 hours $= 24 \times \frac{296,480}{6,700} = 1,056$ lb., nearly, or about 44 lb. per hour. Ans.

(*b*) Size of grate $= \frac{44}{4} = 11$ sq. ft. Ans.

(*c*) Area of heating surface is 45 to 1 of grate surface; consequently, area of heating surface = $11 \times 45 = 495$ sq.ft. Ans.

(1146) (See Art. **1844.**) The air-heating surfaces should be so arranged as to split the air into thin sheets, which will impinge upon the heating surfaces nearly at right angles. The surfaces should be sufficiently extensive to slowly and thoroughly heat the air, without being themselves overheated.

(1147) (See Art. **1849.**) Main current of air is split up into numerous very small currents by the heating surfaces, and the whole volume of air consequently passes over the surfaces and comes into actual contact with them. Owing to the fact that the hot products of combustion flow down drop flues and heat the air at the bottom of the furnace, it follows that the mean density of the hot-air column inside the furnace jacket is decreased to the lowest practicable extent and the draft pressure in the hot-air system is increased to its maximum.

(1148) See Art. **1857.**

(1149) See Art. **1866.**

(1150) See Art. **1872.**

(1151) See Art. **1878.**

(1152) (*a*) See Fig. 765.

(*b*) By opening the valve in the windward cold-air box, and closing the valve in the box on the other side, the furnace can be supplied with air from the high-pressure side of the building whichever way the wind blows.

(1153) (*a*) See Art. **1888.**

(*b*) See Art. **1889.**

(1154) See Art. **1897.**

(1155) See Arts. **1904** and **1905.**

(1156) A furnace of this type is shown in Fig. 746. See description of Fig. 746 for defects.

(1157) (See Art. **1849.**) (*a*) During the process of combustion the hydrogen contained in the gas, by combining with oxygen, is converted into a vapor, which is condensed by the flues and trickles down to the bottom in the form of water.

(*b*) Drain off the water by means of a trap, as shown at *t* in Fig. 751.

(1158) (See Arts. **1858** and **1859.**) The common forms are shown by Figs. 756 and 757. The chief advantage of that shown in Fig. 756 is that the hot-air pipes can be swung around horizontally to suit any position. The advantage of that shown in Fig. 757 is that the hot-air pipes may have the greatest pitch possible. Fig. 756 can be used to advantage only in cellars having high ceilings, or when short leaders are used. Fig. 757 can be used to good advantage in cellars which have low ceilings, or when long leaders are used.

(1159) See Art. **1867.**

(1160) See Art. **1874.**

(1161) See Art. **1879.**

VENTILATION OF BUILDINGS.

(QUESTIONS 1162–1284.)

(1162) (See Art. **1917.**) Dust from wagon roads, streets, and pavements, because it usually contains much pulverized dung, etc.

(1163) See Art. **1925.**

(1164) See Art. **1936.**

(1165) (*a*) and (*b*) (See Art. **1947.**) Dew point for United States about 40° F. Represents about 40 per cent. of humidity.

(1166) See Art. **1955.**

(1167) See Art. **1962.**

(1168) See Art. **1973.**

(1169) (See Art. **1985.**) (*a*) About 20 feet per second, not more; (*b*) about 10 feet per second.

(1170) See Art. **2002.**

(1171) See Art. **1907.**

(1172) (See Art. **1918.**) The names are *saprophytes* and *parasites*.

(1173) See Art. **1926.**

(1174) Yes. (See Art. **1937.**)

(1175) See Art. **1948.**

(1176) (See Art. **1956.**) Since we are told that enough fresh air enters the room to keep the air pure

throughout, it follows that the fresh air is not properly distributed. The inlets and outlets are not properly arranged, and diffusion is not complete.

(1177) (See Art. **1963.**) The *pressure* system is best adapted for schools, because there is no chance of an inflow of cold air from open doors or windows to injure the scholars.

(1178) See Art. **1974.**

(1179) See Arts. **1986** to **1989.**

(1180) See Art. **2003.**

(1181) See Art. **1908.**

(1182) See Art. **1919.**

(1183) (See Art. **1927.**) By this plan of cooling the air, the humidity in the auditorium becomes so high that the people actually feel warm in the cool air, this being due to the lack of proper evaporation of the moisture from their bodies.

(1184) No. (See Arts. **1938** and **1939.**)

(1185) See Art. **1949.**

(1186) (See Art. **1957.**) The CO_2 diffuses uniformly throughout the room. It sometimes happens, however, that, if the room is cold and gas lights are burning, a greater amount of CO_2 is found near the ceiling than at the floor.

(1187) See Arts. **1964** and **1965.**

(1188) (*a*) See Art. **1976.**

(*b*) See Art. **1977.**

(1189) See Art. **1992.**

(1190) See Art. **2004.**

(1191) (*a*) and (*b*) See Art. **1909.**

(1192) (*a*) and (*b*) (See Art. **1920.**) Damp cellar air is the most foul.

(1193) (See Art. **1929.**) As the humidity increases, the percentage of oxygen present becomes less.

(1194) (See Art. **1942.**) The test is made for CO_2 alone, because we have no practicable method of measuring the most objectionable impurities, and because the amount of CO_2 present has been proved to be a fair index of the vitiation.

(1195) (See Art. **1951.**) A gauge pressure of 5 pounds equals $5 + 14.69$, or say 20 pounds absolute pressure, nearly. With this pressure, a hole $\frac{1}{32}$ inch in diameter will pass .03944 pound per hour. Consequently, the number of holes required $= \frac{.5}{.03944} = 13$ holes. Ans.

(1196) See Art. **1958.**

(1197) See Art. **1968.**

(1198) (*a*) and (*b*) See Art. **1979.**

(1199) See Art. **1993.**

(1200) See Art. **2007.**

(1201) See Art. **1910.**

(1202) (See Art. **1921.**) Underground air contains less oxygen and more carbonic acid gas than atmospheric air.

(1203) (See Art. **1931.**) Damp air is lighter than dry air.

(1204) See Art. **1943.**

(1205) (See Arts. **1952** and **1953.**) The air should be passed between cold surfaces so as to lower its temperature below its dew point before it enters or after it leaves the blower. The steam in the air would thus be condensed upon the cold surfaces, whence it would trickle down and be drained off by a special drain pipe.

(1206) (See Art. **1969.**) There is no apparent advantage. The steam coil is best.

(1207) See Art. **1980.**

(1208) See Art. **1994.**

(1209) (See Art. **2008.**) To secure a draft for summer ventilation.

(1210) See Art. **1911.**

(1211) See Art. **1922.**

(1212) See Art. **1933.**

(1213) See Arts. **1944** and **1945.**

(1214) See Art. **1954.**

(1215) (See Art. **1959.**) The warm air should be taken in through the end wall at a point between floor and ceiling, say about 8 feet above the floor, so as to prevent adhesion to the various surfaces.

(1216) (See Art. **1971.**) They do not assist ventilation when the air is still.

(1217) (See Art. **1981.**) Mixing valves should be used.

(1218) See Art. **1995.**

(1219) See Art. **2015.**

(1220) (*a*) See Art. **1914.** (*b*) (See same article.) About $16\frac{1}{4}$ cubic feet. Ans.

(1221) See Art. **1923.**

(1222) (See Art. **1934.**) Two parts of CO_2 per 10,000 parts of air in excess of that contained by the outer atmosphere.

(1223) (*a*) and (*b*) See Art. **1946.**

(1224) (See "Dry Screen," Art. **1954.**) The total area of filtering surface should be from 8 to 10 times the sectional area of the flue. Consequently, the smallest amount of filtering surface which should be allowed is $4 \times 6 \times 8 = 192$ square feet. Ans. A larger filtering surface will give better results.

(1225) See Art. **1960.**

(1226) See Art. **1972.**

(1227) (See Art. **1984.**) (*a*) Raise valve *a* up to its full height and close the door *d*. (*b*) Drop the valve *a* to its full limit, close *b*, and open *d*.

(1228) See Art. **1996.**

(1229) See Art. **2012.**

(1230) (*a*) and (*b*) See Art. **1915.** (*c*) (See same article.) By the amount of CO_2 present.

(1231) (See Art. **1924.**) No, because gases are given off from wet coal.

(1232) (See Art. **1934.**) 3,500 cubic feet. Ans.

(1233) See Arts. **2013** and **2014.**

(1234) (See Art. **2009.**) A valve is placed at the base of the vertical flue which supplies the room above. This valve can be throttled down so as to properly divide the hot-air current.

A TEXTBOOK

ON

PLUMBING, HEATING, AND VENTILATION

INTERNATIONAL CORRESPONDENCE SCHOOLS
SCRANTON, PA.

TABLES AND FORMULAS

SCRANTON
INTERNATIONAL TEXTBOOK COMPANY
A-2

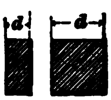
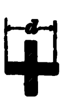
TABLES AND FORMULAS.

In the following pages are contained the principal Tables and Formulas likely to be used by the student in practice. They have been collected from the preceding volumes and put in a convenient form for ready reference. The article number after each formula is the number of the article in which the formula occurs in the text.

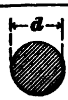
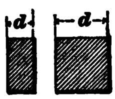
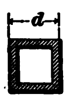
TABLES AND FORMULAS.

TABLES.

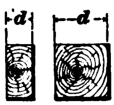
CONSTANTS FOR CAST-IRON PILLARS.

Cross-section of Pillar.	When Both Ends of the Pillar are Flat or Fixed.	When One End of the Pillar is Flat or Fixed, and the Other Round or Movable.	When Both Ends of the Pillar are Round or Movable.
 Round.	281.25	187.5	140.625
 Square or Rectangle.	375.00	250.0	187.500
 Thin Square Tube.	750.00	500.0	375.000
 Thin Round Tube.	562.50	375.0	281.250
 Angle with Equal Sides.	187.50	125.0	93.750
 Cross with Equal Arms.	187.50	125.0	93.750
 I Beam.	$375 \times \frac{A}{A+B}$	$250 \times \frac{A}{A+B}$	$125 \times \frac{A}{A+B}$

CONSTANTS FOR WROUGHT-IRON PILLARS.

Cross-section of Pillar.	When Both Ends of the Pillar are Flat or Fixed.	When One End of the Pillar is Flat or Fixed, and the Other Round or Movable.	When Both Ends of the Pillar are Round or Movable.
 Round.	2,250	1,500	1,125
 Square or Rectangle.	3,000	2,000	1,500
 Thin Square Tube.	6,000	4,000	3,000
 Thin Round Tube.	4,500	3,000	2,250
 Angle with Equal Sides.	1,500	1,000	750
 Cross with Equal Arms	1,500	1,000	750
 I Beam.	$3{,}000 \times \frac{A}{A+B}$	$2{,}000 \times \frac{A}{A+B}$	$1{,}500 \times \frac{A}{A+B}$

CONSTANTS FOR WOODEN PILLARS.

Cross-section of Pillar.	When Both Ends of the Pillar are Flat or Fixed.	When One End of the Pillar is Flat or Fixed, and the Other Round or Movable.	When Both Ends of the Pillar are Round or Movable.
 Round.	187.5	125.00	93.75
 Square or Rectangle.	250.0	166.66	125.00
 Hollow Square Made of Boards.	500.0	333.33	250.00

CONSTANTS FOR TRANSVERSE STRENGTH OF BEAMS.

Materials.	Safe Transverse Strength in Pounds.	Materials.	Safe Transverse Strength in Pounds.
Metals:		Woods:	
Cast Iron.......	100	Birch..........	35
Wrought Iron...	150	Elm	25
Structural Steel	160	Ash............	45
Copper.........	50	Beech..........	30
Brass...........	55	Hickory........	50
		Maple..........	60
		Oak (American)	45
		Pine (Pitch)....	40
		Pine (White)...	30

TENSILE STRENGTHS OF MATERIALS.

Materials.	Breaking Stress in Pounds per Square Inch.	Working Stress in Pounds per Square Inch.
Timber	10,000	600 to 1,200
Cast Iron	16,000	1,500 to 3,500
Wrought Iron	50,000	5,000 to 12,000
Steel	70,000	6,000 to 13,000

CRUSHING STRENGTHS OF MATERIALS.

Materials.	Crushing Strength in Tons per Square Inch.
Cast Iron	40.0
Wrought Iron	18.0
Mild Steel	26.0
Cast Copper	5.0
Cast Brass	4.5
Timber (dry)	3.5
Brick	1.0
Stone	3.0

SHEARING STRENGTHS OF MATERIALS.

Materials.	Greatest Shearing Stress in Pounds per Square Inch.	Safe Shearing Stress in Pounds per Square Inch.
Cast Iron	18,000	1,500 to 3,000
Wrought Iron	40,000	4,000 to 10,000
Steel	60,000	5,000 to 12,000

SPECIFIC GRAVITIES AND WEIGHTS PER CUBIC FOOT.

METALS.

Substance.	Specific Gravity.	Weight per Cubic Foot in Pounds.
Osmium	23.00	1,437.5
Platinum	21.50	1,343.8
Gold	19.50	1,218.8
Mercury	13.60	850.0
Lead (cast)	11.35	709.4
Silver	10.50	656.3
Copper (cast)	8.79	549.4
Brass	8.38	523.8
Wrought Iron	7.68	480.0
Cast Iron	7.21	450.0
Steel	7.84	490.0
Tin (cast)	7.29	455.6
Zinc (cast)	6.86	428.8
Antimony	6.71	419.4
Aluminum	2.50	156.3

WOODS.

Substance.	Specific Gravity.	Weight per Cubic Foot in Pounds.
Ash	.845	52.80
Beech	.852	53.25
Cedar	.561	35.06
Cork	.240	15.00
Ebony (American)	1.331	83.19
Lignum-vitæ	1.333	83.30
Maple	.750	46.88
Oak (old)	1.170	73.10
Spruce	.500	31.25
Pine (yellow)	.660	41.20
Pine (white)	.554	34.60
Walnut	.671	41.90

LIQUIDS.

Substance.	Specific Gravity.	Weight per Cubic Foot in Pounds.
Acetic Acid	1.062	66.4
Nitric Acid	1.217	76.1
Sulphuric Acid	1.841	115.1
Muriatic Acid	1.200	75.0
Alcohol	.800	50.0
Turpentine	.870	54.4
Sea Water (ordinary)	1.026	64.1
Milk	1.032	64.5

GASES.

At 32° F., and under a Pressure of One Atmosphere.

Substance.	Specific Gravity.	Weight per Cubic Foot in Pounds.
Atmospheric Air	1.0000	.08073
Carbonic Acid	1.5290	.12344
Carbonic Oxide	.9674	.07810
Chlorine	2.4400	.19700
Oxygen	1.1056	.08925
Nitrogen	.9736	.07860
Smoke (bituminous coal)	.1020	.00815
Smoke (wood)	.0900	.00727
*Steam at 212° F.	.4700	.03790
Hydrogen	.0692	.00559

* The specific gravity of steam at any temperature and pressure compared with air at the same temperature and pressure is 0.622.

MISCELLANEOUS.

Substance.	Specific Gravity.	Weight per Cubic Foot in Pounds.
Emery	4.00	250
Glass (average)	2.80	175
Chalk	2.78	174
Granite	2.65	166
Marble	2.70	169
Stone (common)	2.52	158
Salt (common)	2.13	133
Soil (common)	1.98	124
Clay	1.93	121
Brick	1.90	118
Plaster Paris (average)	2.00	125
Sand	1.80	113

COEFFICIENTS OF FRICTION.

Description of Surfaces in Contact.	Disposition of Fibers.	State of the Surfaces.	Coefficient of Friction.
Oak on Oak	Parallel	Dry	.48
Oak on Oak	Parallel	Soaped	.16
Wrought Iron on Oak	Parallel	Dry	.62
Wrought Iron on Oak	Parallel	Soaped	.21
Cast Iron on Oak	Parallel	Dry	.49
Cast Iron on Oak	Parallel	Soaped	.19
Wrought Iron on Cast Iron	—	Slightly Unctuous	.18
Wrought Iron on Bronze	—	Slightly Unctuous	.18
Cast Iron on Cast Iron	—	Slightly Unctuous	.15

CONSTANTS FOR FLOW OF WATER THROUGH PIPES.

$v_m =$	0.1	0.2	0.3	0.4	0.5	0.6
$f =$	.0686	.0527	.0457	.0415	.0387	.0365
$v_m =$	0.7	0.8	0.9	1	1¼	1½
$f =$	.0349	.0336	.0325	.0315	.0297	.0284
$v_m =$	2	3	4	6	8	12
$f =$	.0265	.0243	.023	.0214	.0205	.0193

WEIGHT AND THICKNESS OF SHEET LEAD.

Weight in Pounds per Sq. Ft.	Thickness in Inches.
8	$\frac{2}{15}$
7½	⅛
6	$\frac{1}{10}$
5	$\frac{1}{12}$
4	$\frac{1}{15}$
3	$\frac{1}{20}$

WEIGHT AND THICKNESS OF SHEET COPPER.

Weight in ounces per square foot..........	10	12	14	16	18	20
Thickness in inches......	.013	.016	.019	.022	.025	.029

WEIGHT AND THICKNESS OF BLACK SHEET IRON.

Number of Gauge.	Thickness in Inches.	Black Iron. Weight in Pounds per Sq. Ft.	Galvanized Iron. Weight in Pounds per Sq. Ft.
1	.300	12.0375	....
2	.284	11.3955	....
3	.259	10.3924	....
4	.238	9.5497	....
5	.220	8.8275	....
6	.203	8.1454	....
7	.180	7.2225	....
8	.165	6.6206	....
9	.148	5.9385	....
10	.134	5.3767	....
11	.120	4.8150	....
12	.109	4.3736	....
13	.095	3.8119	....
14	.083	3.3304	....
15	.072	2.8890	....
16	.065	2.6081	3.00
17	.058	2.3272	2.69
18	.049	1.9661	2.31
19	.042	1.6852	2.07
20	.035	1.4044	1.75
21	.032	1.2840	1.50
22	.028	1.1235	1.32
23	.025	1.0031	1.19
24	.022	0.8827	1.06
25	.020	0.8025	1.00
26	.018	0.7222	0.96
27	.016	0.6420	0.88
28	.014	0.5617	0.75
29	.013	0.5216	0.69
30	.012	0.4815	0.60

WEIGHT AND THICKNESS OF SHEET ZINC.

Weight in ounces per square foot	10	12	14	16	18	20
Thickness in inches	.0311	.0457	.0534	.0611	.0686	.0761

WEIGHT OF BRASS TUBING.

Nominal Diameter in Inches.	Weight in Lb. per Lineal Foot.	Nominal Diameter in Inches.	Weight in Lb. per Lineal Foot.
1/8	.25	2	4.00
1/4	.43	2 1/2	5.75
3/8	.62	3	8.30
1/2	.90	3 1/2	10.90
3/4	1.25	4	12.70
1	1.70	4 1/2	13.90
1 1/4	2.50	5	15.75
1 1/2	3.00	6	20.60

WEIGHT PER FOOT OF LEAD PIPE AND TIN-LINED LEAD PIPE.

Inside Diameter.	*AAA* Brooklyn		*AA* Extra Strong.		*A* Strong.		*B* Medium.		*C* Light.		*D* Extra Light.		*E* Fountain.	
In.	Lb.	Oz.	Lb.	Oz.	Lb.	Oz.	Lb.	Oz.	Lb.	Oz.	Lb.	Oz.	Lb.	Oz.
3/8	1	12	1	8	1	4	1	0	0	12	0	10	0	7
7/16	....		....		....		1	0	0	13	......		......	
1/2	3	0	2	0	1	12	1	4	1	0	0	12	0	9
5/8	3	8	2	12	2	8	2	0	1	8	1	0	0	12
3/4	4	12	3	8	3	0	2	4	1	12	1	4	1	0
1	6	0	4	12	4	0	3	4	2	8	2	0	1	8
1 1/4	6	12	5	12	4	12	3	12	3	0	2	8	2	0
1 1/2	8	8	7	8	6	8	5	0	4	4	3	8	3	0
1 3/4	10	0	8	8	7	0	6	0	5	0	4	0	......	
2	11	12	9	0	8	0	7	0	6	0	4	12	......	

LEAD TUBING.

1/16 in......... ¾ oz. per ft.	5/32 in.........2¼ oz. per ft.
⅛ in.........1¼ oz. per ft.	¼ in...5, 6, 8, 13 oz. per ft.

LEAD WASTE PIPE.

1½ in.......... 2 lb. per ft.	4 in....5, 6, and 8 lb. per ft.
2 in...... 3 and 4 lb. per ft.	4½ in... 8 and 10 lb. per ft.
2½ in...4 and 6 lb. per ft.	5 in..8, 10, and 12 lb. per ft.
3 in.....4½ and 5 lb. per ft.	6 in.... 12 lb. and up per ft.

PURE BLOCK-TIN PIPE.

¼ in. *AAA*. 5 oz. per ft.	⅝ in. *AA*.... 9 oz. per ft.
¼ in. *AA*... 3½ oz. per ft.	¾ in. *AAA*..13 oz. per ft.
¼ in. .... 8 oz. per ft.	¾ in. *AA*....11 oz. per ft.
5/16 in. *AAA*. 6½ oz. per ft.	1 in. *AAA*..17 oz. per ft.
5/16 in. *AA*... 4 oz. per ft.	1 in. *AA*....14 oz. per ft.
⅜ in. *AAA*. 7 oz. per ft.	1¼ in. *AAA*..26 oz. per ft.
⅜ in. *AA*... 4 oz. per ft.	1¼ in. *AA*....18 oz. per ft.
7/16 in. *AAA*. 7 oz. per ft.	1½ in. *AAA*..36 oz. per ft.
½ in. *AAA*.10 oz. per ft.	1½ in. *AA*....24 oz. per ft.
½ in. *AA*... 6 oz. per ft.	2 in. *AAA*..40 oz. per ft.
½ in. .... 8 oz. per ft.	2 in. *AA*....26 oz. per ft.
⅝ in. *AAA*.11 oz. per ft.	

SIZES OF WIPING CLOTHS.

For ½″ and ¾″ pipe, 3½ × 4 inches, 6 layers of cloth.
For 1″ pipe, 4 × 4½ inches, 8 layers of cloth.
For 1¼″ and 1½″ pipe, 4¼ × 4½ inches, 8 layers of cloth.
For 2″ pipe, 4½ × 5 inches, 8 layers of cloth.
For 3″ pipe, 5 × 6 inches, 8 layers of cloth.
For 4″ pipe, 6 × 7 inches, 8 or 10 layers of cloth.

STANDARD DIMENSIONS OF WROUGHT-IRON PIPE.

Nominal Internal Diameter in Inches.	Actual Internal Diameter in Inches.	Actual External Diameter in Inches.	Thickness of Metal in Inches.	Area of Internal Diameter in Square Inches.	Weight in Pounds per Lineal Foot.
1/8	0.270	0.405	.068	0.0572	0.243
1/4	0.364	0.540	.088	0.1041	0.422
3/8	0.494	0.675	.091	0.1916	0.561
1/2	0.623	0.840	.109	0.3048	0.845
3/4	0.824	1.050	.133	0.5333	1.126
1	1.048	1.315	.134	0.8627	1.670
1 1/4	1.380	1.660	.140	1.4960	2.258
1 1/2	1.610	1.900	.145	2.0380	2.694
2	2.067	2.375	.154	3.3550	3.667
2 1/2	2.468	2.875	.204	4.7830	5.773
3	3.067	3.500	.217	7.3880	7.547
3 1/2	3.548	4.000	.226	9.8870	9.055
4	4.026	4.500	.237	12.7300	10.728
4 1/2	4.508	5.000	.246	15.9390	12.492
5	5.045	5.563	.259	19.9900	14.564
6	6.065	6.625	.280	28.8890	18.767

Wrought-iron pipes are made in lengths from about 15 to 20 feet.

FALL OF DRAIN PIPES.

Diameter.............	2	3	4	5	6	7	8	9	10 inches.
Length to 1 ft. of fall..	20	30	40	50	60	70	80	90	100 feet.

SYSTEM OF SCREW THREADS FOR WROUGHT-IRON PIPE, BRIGGS' STANDARD.

Nominal Internal Diameter in Inches.	Number of Threads per Inch.	Length of Perfect Thread in Inches.
1/8	27	.19
1/4	18	.29
3/8	18	.30
1/2	14	.39
3/4	14	.40
1	11 1/2	.51
1 1/4	11 1/2	.54
1 1/2	11 1/2	.55
2	11 1/2	.58
2 1/2	8	.89
3	8	.95
3 1/2	8	1.00
4	8	1.05
4 1/2	8	1.10
5	8	1.16
6	8	1.26

All pipe ends are made conical, the taper being 3/4 inch of diameter per foot of length.

LEAD SOIL AND WASTE PIPES.

Diameter in Inches.	Weight in Lb. per Lineal Foot.
1 1/4	2 1/2
1 1/2	3
2	4
3	6
4 and 4 1/2	8

MELTING POINTS OF METALS.

Metal.	Temperature in Degrees F.	Metal.	Temperature in Degrees F.
Cast Iron.......	2,192	Zinc..........	680
Copper.........	2,100	Lead..........	626
Silver..........	1,800	Bismuth.......	505
Brass (common).	1,900	Tin...........	446
Antimony......	1,000	Sulphur.......	228

The melting or fusing point varies greatly according to the purity of the metal, and the melting points of alloys vary according to the composition. The temperatures given above are fair averages.

SOLDERS.

Variety.	Hard.			Soft.			Fusing Point.
	Zinc.	Copper.	Silver	Tin.	Lead.	Bismuth.	
Spelter, hardest..	1	2	....	....	....	....	700°
Spelter, hard.....	2	3	....	....	....	....	....
Spelter, soft.....	1	1	....	....	....	....	550°
Spelter, fine......	2	2	1/4	....	....	....	....
Silver, hard......	....	1	4	....	....	....	....
Silver, medium...	....	1	3	....	....	....	....
Silver, soft.......	....	1	2	....	....	....	....
Plumbers', coarse.	....	....	....	1	3	....	480°
Plumbers', ordinary..........	....	....	....	1	2	....	441°
Plumbers', fine...	....	....	....	2	3	....	400°
Tinners'.........	....	....	....	1	1	....	370°
For tin pipe......	....	....	....	3	2	....	330°
For tin pipe......	....	....	....	4	4	1	....

FLUXES.

Flux.	Metals to be Joined.
Resin	Lead, tin, copper, brass, and tinned metals (used with the copper bit or blowpipe).
Tallow (without salt)	Lead, tin, or tinned metals (used with the blowpipe or wiping process).
Sal-ammoniac	Copper, brass, and iron (used with the copper bit or blowpipe).
Muriatic acid, or hydrochloric acid	Dirty zinc (used with copper bit).
Chloride of zinc	Clean zinc, copper, brass, tin, and tinned metals (used with copper bit or blowpipe).
Resin and sweet oil	Lead and tin tubes (used with copper bit or blowpipe).
Borax	Iron, steel, copper, and brass (used with blowpipe).

LENGTH OF WIPE JOINTS FOR LEAD PIPE.

Diameter of Pipe, Inches.	Length of Joint, Inches.	Diameter of Pipe, Inches.	Length of Joint, Inches.	Diameter of Pipe, Inches.	Length of Joint, Inches.
1/2	2 1/8	1 1/4 water	3	2 waste	2 1/4
5/8	2 1/4	1 1/4 waste	2	2 1/2 waste	2 1/2
3/4	2 1/2	1 1/2 waste	3 1/4	3 waste	2 1/2
1	2 3/4	1 1/2 waste	2 1/4	4 waste	3

LEAD PIPE TACKS.

Size of Pipe in Inches.	Vertical Pipe. Distance Apart of Tacks in Inches.		Horizontal Pipe. Distance Apart of Tacks in Inches.	
	Hot.	Cold.	Hot.	Cold.
3/8	18	24	12	16
1/2	19	25	14	17
5/8	20	26	15	18
3/4	21	27	16	19
1	22	28	17	20
1 1/4	23	29	18	21
1 1/2	24	30	18	22

SIZES OF WATER SUPPLY PIPES.

Supply Branches.	Low Pressure. (Below 20 Lb.)	High Pressure. (Above 20 Lb.)
To bath cocks	3/4 to 1"	1/2 to 3/4"
To basin cocks	1/2"	3/8 to 1/2"
To W. C. flush tank	1/2"	1/2"
To W. C. flush valve	1 to 1 1/4"	3/4 to 1"
To sitz or foot baths	1/2 to 3/4"	1/2"
To kitchen sinks	5/8 to 3/4"	1/2 to 5/8"
To pantry sinks	1/2"	3/8 to 1/2"
To slop sinks	5/8 to 3/4"	1/2 to 5/8"
To urinals	5/8 to 3/4"	1/2 to 5/8"

THE PROPERTIES OF SATURATED STEAM.

Pressure above Vacuum in Pounds per Square Inch.	Temperature, Fahrenheit Degrees.	Quantities of Heat in British Thermal Units.			Weight of a Cubic Foot of Steam in Pounds.	Volume.	
		Required to Raise Temperature of the Water from 32° to t°.	Total Latent Heat at Pressure P.	Total Heat above 32°.		Of a Pound of Steam in Cubic Feet.	Ratio of Vol. of Steam to Vol. of Eq. Weight of Dist. Water at Temp. of Maximum Density.
1	2	3	4	5	6	7	8
p	t	q	L	H	W	V	R
1	102.018	70.040	1043.015	1113.055	.003027	330.4	20623
2	126.302	94.368	1026.094	1120.462	.005818	171.9	10730
3	141.654	109.764	1015.380	1125.144	.008522	117.3	7325
4	153.122	121.271	1007.370	1128.641	.011172	89.51	5588
5	162.370	130.563	1000.899	1131.462	.013781	72.56	4530
6	170.173	138.401	995.441	1133.842	.016357	61.14	3816
7	176.945	145.213	990.695	1135.908	.018908	52.89	3302
8	182.952	151.255	986.485	1137.740	.021436	46.65	2912
9	188.357	156.699	982.690	1139.389	.023944	41.77	2607
10	193.284	161.660	979.232	1140.892	.026437	37.83	2361
11	197.814	166.225	976.050	1142.275	.028911	34.59	2159
12	202.012	170.457	973.098	1143.555	.031376	31.87	1990
13	205.929	174.402	970.346	1144.748	.033828	29.56	1845
14	209.604	178.112	967.757	1145.869	.036265	27.58	1721
14.69	212.000	180.531	966.069	1146.600	.037928	26.37	1646
15	213.067	181.608	965.318	1146.926	.038688	25.85	1614
16	216.347	184.919	963.007	1147.926	.041109	24.33	1519
17	219.452	188.056	960.818	1148.874	.043519	22.98	1434
18	222.424	191.058	958.721	1149.779	.045920	21.78	1359
19	225.255	193.918	956.725	1150.643	.048312	20.70	1292

1	2	3	4	5	6	7	8
p	*t*	*q*	*L*	*H*	*W*	*V*	*R*
20	227.964	196.655	954.814	1151.469	.050696	19.73	1231.0
22	233.069	201.817	951.209	1153.026	.055446	18.04	1126.0
24	237.803	206.610	947.861	1154.471	.060171	16.62	1038.0
26	242.225	211.089	944.730	1155.819	.064870	15.42	962.3
28	246.376	215.293	941.791	1157.084	.069545	14.38	897.6
30	250.293	219.261	939.019	1158.280	.074201	13.48	841.3
32	254.002	223.021	936.389	1159.410	.078839	12.68	791.8
34	257.523	226.594	933.891	1160.485	.083461	11.98	748.0
36	260.883	230.001	931.508	1161.509	.088067	11.36	708.8
38	264.093	233.261	929.227	1162.488	.092657	10.79	673.7
40	267.168	236.386	927.040	1163.426	.097231	10.28	642.0
42	270.122	239.389	924.940	1164.329	.101794	9.826	613.3
44	272.965	242.275	922.919	1165.194	.106345	9.403	587.0
46	275.704	245.061	920.968	1166.029	.110884	9.018	563.0
48	278.348	247.752	919.084	1166.836	.115411	8.665	540.9
50	280.904	250.355	917.260	1167.615	.119927	8.338	520.5
52	283.381	252.875	915.494	1168.369	.124433	8.037	501.7
54	285.781	255.321	913.781	1169.102	.128928	7.756	484.2
56	288.111	257.695	912.118	1169.813	.133414	7.496	467.9
58	290.374	260.002	910.501	1170.503	.137892	7.252	452.7
60	292.575	262.248	908.928	1171.176	.142362	7.024	438.5
62	294.717	264.433	907.396	1171.829	.146824	6.811	425.2
64	296.805	266.566	905.900	1172.466	.151277	6.610	412.6
66	298.842	268.644	904.443	1173.087	.155721	6.422	400.8
68	300.831	270.674	903.020	1173.694	.160157	6.244	389.8
70	302.774	272.657	901.629	1174.286	.164584	6.076	379.3
72	304.669	274.597	900.269	1174.866	.169003	5.917	369.4
74	306.526	276.493	898.938	1175.431	.173417	5.767	360.0
76	308.344	278.350	897.635	1175.985	.177825	5.624	351.1
78	310.123	280.170	896.359	1176.529	.182229	5.488	342.6
80	311.866	281.952	895.108	1177.060	.186627	5.358	334.5
82	313.576	283.701	893.879	1177.580	.191017	5.235	326.8
84	315.250	285.414	892.677	1178.091	.195401	5.118	319.5
86	316.893	287.096	891.496	1178.592	.199781	5.006	312.5
88	318.510	288.750	890.335	1179.085	.204155	4.898	305.8

1	2	3	4	5	6	7	8
p	*t*	*q*	*L*	*H*	*W*	*V*	*R*
90	320.094	290.373	889.196	1179.569	.208525	4.796	299.4
92	321.653	291.970	888.075	1180.045	.212892	4.697	293.2
94	323.183	293.539	886.972	1180.511	.217253	4.603	287.3
96	324.688	295.083	885.887	1180.970	.221604	4.513	281.7
98	326.169	296.601	884.821	1181.422	.225950	4.426	276.3
100	327.625	298.093	883.773	1181.866	.230293	4.342	271.1
105	331.169	301.731	881.214	1182.945	.241139	4.147	258.9
110	334.582	305.242	878.744	1183.986	.251947	3.969	247.8
115	337.874	308.621	876.371	1184.992	.262732	3.806	237.6
120	341.058	311.885	874.076	1185.961	.273500	3.656	228.3
125	344.136	315.051	871.848	1186.899	.284243	3.518	219.6
130	347.121	318.121	869.688	1187.809	.294961	3.390	211.6
135	350.015	321.105	867.590	1188.695	.305659	3.272	204.2
140	352.827	324.003	865.552	1189.555	.316338	3.161	197.3
145	355.562	326.823	863.567	1190.390	.326998	3.058	190.9
150	358.223	329.566	861.634	1191.200	.337643	2.962	184.9
160	363.346	334.850	857.912	1192.762	.358886	2.786	173.9
170	368.226	339.892	854.359	1194.251	.380071	2.631	164.3
180	372.886	344.708	850.963	1195.671	.401201	2.493	155.6
190	377.352	349.329	847.703	1197.032	.422280	2.368	147.8
200	381.636	353.766	844.573	1198.339	.443310	2.256	140.8
210	385.759	358.041	841.556	1199.597	.464295	2.154	134.5
220	389.736	362.168	838.642	1200.810	.485237	2.061	128.7
230	393.575	366.152	835.828	1201.980	.506139	1.976	123.3
240	397.285	370.008	833.103	1203.111	.527003	1.898	118.5
250	400.883	373.750	830.459	1204.209	.547831	1.825	114.0
260	404.370	377.377	827.896	1205.273	.568626	1.759	109.8
270	407.755	380.905	825.401	1206.306	.589390	1.697	105.9
280	411.048	384.337	822.973	1207.310	.610124	1.639	102.3
290	414.250	387.677	820.609	1208.286	.630829	1.585	99.0
300	417.371	390.933	818.305	1209.238	.651506	1.535	95.8

EXPANSION AND WEIGHT OF PURE WATER FROM 32° TO 390° F.

1	2	3	4	1	2	3	4
Temperature.	Comparative Volume.	Comparative Density.	Weight of 1 Cu. Ft.	Temperature.	Comparative Volume.	Comparative Density.	Weight of 1 Cu. Ft.
Fahr.	Water at 32° = 1.	Water at 32° = 1.	Pounds.	Fahr.	Water at 32° = 1.	Water at 32° = 1.	Pounds.
32.0°	1.00000	1.00000	62.418	135.0°	1.01539	0.98484	61.472
35.0	0.99993	1.00007	62.422	140.0	1.01690	0.98339	61.381
39.1	0.99989	1.00011	62.425	145.0	1.01839	0.98194	61.291
40.0	0.99989	1.00011	62.425	150.0	1.01989	0.98050	61.201
45.0	0.99993	1.00007	62.422	155.0	1.02164	0.97882	61.096
46.0	1.00000	1.00000	62.418	160.0	1.02340	0.97714	60.991
50.0	1.00015	0.99985	62.409	165.0	1.02589	0.97477	60.843
52.3	1.00029	0.99971	62.400	170.0	1.02690	0.97380	60.783
55.0	1.00038	0.99961	62.394	175.0	1.02906	0.97193	60.665
60.0	1.00074	0.99926	62.372	180.0	1.03100	0.97006	60.548
62.0	1.00101	0.99899	62.355	185.0	1.03300	0.96828	60.430
65.0	1.00119	0.99881	62.344	190.0	1.03500	0.96632	60.314
70.0	1.00160	0.99832	62.313	195.0	1.03700	0.96440	60.198
75.0	1.00239	0.99771	62.275	200.0	1.03889	0.96256	60.081
80.0	1.00299	0.99702	62.240	205.0	1.04140	0.96020	59.930
85.0	1.00379	0.99622	62.182	210.0	1.04340	0.95840	59.820
90.0	1.00459	0.99543	62.133	212.0	1.04440	0.95750	59.760
95.0	1.00554	0.99449	62.074	230.0	1.05290	0.94990	59.360
100.0	1.00639	0.99365	62.022	250.0	1.06280	0.94110	58.750
105.0	1.00739	0.99260	61.960	270.0	1.07270	0.93230	58.180
110.0	1.00889	0.99119	61.868	290.0	1.08380	0.92270	57.590
115.0	1.00989	0.99021	61.807	298.0	1.08990	0.91750	57.270
120.0	1.01139	0.98874	61.715	338.0	1.11180	0.89940	56.140
125.0	1.01239	0.98808	61.654	366.0	1.13010	0.88500	55.290
130.0	1.01390	0.98630	61.563	390.0	1.14440	0.87380	54.540

WEIGHT OF CAST-IRON SOIL PIPES.

Diameter in Inches.	Weight in Lb. per Lineal Foot.
2	5½
3	9½
4	13
5	17
6	20
7	27
8	33½
10	45
12	54

WROUGHT-IRON AND STEEL SOIL AND WASTE PIPES.

Diameter in Inches.	Thickness in Inches.	Weight in Lb. per Lineal Foot.
1½	.14	2.68
2	.15	3.61
2½	.20	5.74
3	.21	7.54
3½	.22	9.00
4	.23	10.66
4½	.24	12.34
5	.25	14.50
6	.28	18.76
7	.30	23.27
8	.32	28.18
9	.34	33.70
10	.36	40.06
11	.37	45.02
12	.37	48.98

BRASS PIPES FOR HOUSE DRAINAGE.

Diameter in Inches.	Thickness in Inches.	Weight in Lb. per Lineal Foot.
1½	.14	2.84
2	.15	3.82
2½	.20	6.08
3	.21	7.92
3½	.22	9.54
4	.23	11.29
4½	.24	13.08
5	.25	15.37
6	.28	19.88

BRASS FERRULES.

Diameter in Inches.	Weight of 1 Ferrule.	
	Lb.	Oz.
2¼	1	0
3½	1	12
4½	2	8

SOLDERING NIPPLES.

Diameter in Inches.	Weight of 1 Ferrule.	
	Lb.	Oz.
1½	0	8
2	0	14
2½	1	6
3	2	0
4	3	8

HOUSE DRAINS TO CARRY OFF RAIN WATER.

Diameter in Inches.	Fall of Pipes. ¼ Inch per Foot.	Fall of Pipes. ½ Inch per Foot.
6	5,000 sq. ft. of drainage area.	7,500 sq. ft. of drainage area.
7	6,900 sq. ft. of drainage area.	10,300 sq. ft. of drainage area.
8	9,100 sq. ft. of drainage area.	13,600 sq. ft. of drainage area.
9	11,600 sq. ft. of drainage area.	17,400 sq. ft. of drainage area.

PRESSURE OF GAS.

Increase of pressure for every 10 feet in rise of pipes...... (Inches of water).	0.	.0147	.0293	.044	.058	.073	.088	.102
Density of gas.......	1.	.9	.8	.7	.6	.5	.4	.3

PRESSURES AT BURNERS.

Argand burners.................... .2 inch of water.
Batswing burners.................. .5 inch of water.
Incandescent burners............... .5 or more.
Regenerative lamps................. .5 to 1 or more.
Atmospheric burners ....1.0 or more.

LOSS OF LIGHT BY GLASS GLOBES.

Ground glass globes............ 10 to 30 per cent.
Opal glass globes .... 30 to 40 per cent.
Colored glass globes .... 40 to 60 per cent.

CANDLE POWER BY BUNSEN'S PHOTOMETER.

Candle Power.	Distance Between Flame and Diaphragm in Inches.	Candle Power.	Distance Between Flame and Diaphragm in Inches.
1	50.00	21	17.91
2	41.42	22	17.57
3	36.61	23	17.25
4	33.33	24	16.95
5	30.90	25	16.67
6	28.98	26	16.40
7	27.43	27	16.14
8	26.12	28	15.90
9	25.00	29	15.66
10	24.04	30	15.43
11	23.17	31	15.22
12	22.40	32	15.02
13	21.71	33	14.83
14	21.09	34	14.64
15	20.52	35	14 45
16	20.00	36	14.28
17	19.52	37	14.12
18	19.07	38	13.96
19	18.66	39	13.80
20	18.27	40	13.65

CAPACITY OF GAS PIPES.

Diameter of Pipe.	Maximum Length.	Capacity per Hour.	
		Coal Gas.	Gasoline Gas.
Inches.	Feet.	Cubic Feet.	Cubic Feet.
¼	6	10	
⅜	20	15	10
½	30	30	20
¾	50	100	75
1	70	175	125
1¼	100	300	200
1½	150	500	350
2	200	1,000	700
2½	300	1,500	1,100
3	450	2,250	1,500
4	600	3,750	2,500

HEAT DEVELOPED BY COMBUSTION OF GAS.

	Heat Units per Lb.
Hydrogen, burned to H_2O	62,000
Carbon, burned to CO_2	14,500
Carbon, burned to CO	4,400
Carbon monoxide, burned to CO_2	10,100
	per Cu. Ft.
Coal gas burned to CO_2	600 to 800

CURRENT TAKEN BY LAMPS.

110 Volts.		55 Volts.
.5 amp.	16 c.p. lamp	1 amp.
1.0 amp.	32 c.p. lamp	2 amp.
1.5 amp.	50 c.p. lamp	3 amp.
3.0 amp.	100 c.p. lamp	6 amp.

COPPER WIRE DATA FOR ELECTRICAL INSTALLATIONS.

AMERICAN OR B. & S. GAUGE.

Gauge No.	Diameter Mils (d). 1 mil = .001 in.	Area.		Weight and Length.			Resistance. Ohms per 1,000 Feet.	Current Allowed. Amperes.	Gauge No.
		Circular Mils (d^2).	Square Inches ($d^2 \times .7854$).	Pounds per 1,000 Feet.	Pounds per Mile.	Feet per Pound.			
0000	460.000	211,600.00	.166190	639.33	3,375.7	1.56	.051	175	0000
000	409.640	167,805.00	.131790	507.01	2,677.0	1.97	.064	145	000
00	364.800	133,079.00	.104520	402.09	2,123.0	2.49	.081	120	00
0	324.950	105,592.00	.082932	319.04	1,684.5	3.13	.102	100	0
1	289.300	83,694 00	.065733	252.88	1,335.2	3.95	.129	95	1
2	257.630	66,373.00	.052130	200.54	1,058.8	4.99	.163	70	2
3	229.420	52,634.00	.041339	159.03	839.68	6.29	.205	60	3
4	204.310	41,742.00	.032784	126.12	665.91	7.93	.259	50	4
5	181.940	33,102.00	.025998	100.01	528.05	10.00	.326	45	5
6	162.020	26.250.00	.020617	79.32	418.81	12.61	411	35	6
7	144.280	20,817.00	.016349	62.90	332.11	15.90	.519	30	7
8	128.490	16,509.00	.012966	49.88	263.37	20.05	.652	25	8
9	114.430	13,094.00	.010284	39.56	208.88	25.28	.824		9
10	101.890	10,381.00	.0081532	31.37	165.63	31.88	1.040	20	10
11	90.742	8,234.10	.0064670	24.88	137.37	40.20	1.311		11
12	80.808	6,529.90	.0051286	19.73	104.18	50.69	1.653	15	12
13	71.961	5,178.40	.0040671	15.65	82.632	63.91	2.084		13
14	64.084	4,106.80	.0032254	12.41	65.525	80.59	2.628	10	14

CARRYING CAPACITY OF FUSES.

Diam. in Mils.	B. & S. Gauge (approx.).	Amperes.
.017	25	3
.020	24	4
.032	20	7
.042	18-17	10
.056	15	15
.065	14	18
.075	13-12	25
.085	12-11	28
.096	11-10	31
.111	9	36
.130	8	59
.150	7-6	70

CURRENT CAPACITY OF CABLES.

Area in Circular Mils.	Current in Amperes.	Area in Circular Mils.	Current in Amperes.
200,000	200	1,100,000	673
300,000	272	1,200,000	715
400,000	336	1,300,000	756
500,000	393	1,400,000	796
600,000	445	1,500,000	835
700,000	494	1,600,000	873
800,000	541	1,700,000	910
900,000	586	1,800,000	946
1,000,000	630	1,900,000	981
		2,000,000	1,015

REFLECTING POWER.

	Per Cent.		Per Cent.
Polished silver	97	Polished zinc	81
Polished brass	93	Polished iron	77
Polished copper	93	Bright tin	85
Polished steel	83	Glass	10

CONDUCTING POWER.

Silver	100	Cast iron	17
Copper	77	Zinc	20
Brass	33	Tin	15
Steel	12	Lead	8.5

ABSORBING AND EMITTING POWER.

Lampblack, dry	100	Steel	17
White lead, dry powder	100	Polished brass	7
Paper	98	Polished copper	7
Glass	90	Polished silver	3

EXPANSION OF MATERIALS.

Material.	Increase of Length in 1 Foot for an Increase in Temperature of 1° F.	Material.	Increase of Length in 1 Foot for an Increase in Temperature of 1° F.
	Inches.		Inches.
Cast iron	.0000740	Lead	.0001900
Wrought iron	.0000823	Tin	.0001692
Steel tubes	.0000719	Glass	.0000550
Brass	.0001244	Brick	.0000144
Copper	.0001146	Firebrick	.0000333
Zinc	.0001961	Marble	.0000566

LATENT HEAT.

Substance.	Temperature of Fusion.	Temperature of Vaporization.	Latent Heat of Fusion. B. T. U.	Latent Heat of Vaporization. B. T. U.
Water	32°	212°	142.65	966.069
Mercury	− 37.8°	662°	5.09	157
Sulphur	228.3°	824°	13.26	
Tin	446°		25.65	
Lead	626°		9.67	
Zinc	680°	1,900°	50.63	493
Alcohol	Unknown	173°		372
Oil of turpentine	14°	313°		124
Linseed oil		600°		

SPECIFIC HEAT.

SOLIDS.

Copper	0.0951	Cast iron	0.1298
Gold	0.0324	Lead	0.0314
Wrought iron	0.1138	Platinum	0.0324
Steel (soft)	0.1165	Silver	0.0570
Steel (hard)	0.1175	Tin	0.0562
Zinc	0.0956	Ice	0.5040
Brass	0.0939	Sulphur	0.2026
Glass	0.1937	Charcoal	0.2410

LIQUIDS.

Water at 62°	1.0000	Lead (melted)	0.0402
Alcohol	0.7000	Sulphur (melted)	0.2340
Mercury	0.0333	Tin (melted)	0.0637
Benzine	0.4500	Sulphuric acid	0.3350
Glycerine	0.5550	Oil of turpentine	0.4260

GASES.

Air 0.23751	Carbonic oxide 0.2479
Oxygen............0.21751	Carbonic acid........0.2170
Nitrogen 0.24380	Olefiant gas.........0.4040
Hydrogen 3.40900	

PROPERTIES OF AIR

at a pressure of 14.7 lb. per sq. in.

Temperature, F.	Weight per Cubic Foot, Lb.	B. T. U. Given Up by 1 Cu. Ft. of Air in Cooling to 0° from	Temperature, F.	Weight per Cubic Foot, Lb.	B. T. U. Given Up by 1 Cu. Ft. of Air in Cooling to 0° from
0	.08635	.0000	75	.07424	1.3225
2	.08597	.0408	80	.07355	1.3975
4	.08560	.0813	85	.07288	1.4713
6	.08523	.1214	90	.07222	1.5438
8	.08487	.1613	95	.07157	1.6149
10	.08451	.2007	100	.07093	1.6847
12	.08415	.2398	110	.06968	1.8205
14	.08380	.2786	120	.06848	1.9518
16	.08344	.3171	130	.06732	2.0786
18	.08309	.3552	140	.06620	2.2013
20	.08275	.3931	150	.06511	2.3196
24	.08206	.4678	160	.06406	2.4344
28	.08139	.5413	170	.06305	2.5458
32	.08073	.6136	180	.06206	2.6532
36	.08008	.6847	190	.06111	2.7577
40	.07944	.7547	200	.06018	2.8587
45	.07865	.8406	210	.05929	2.9572
50	.07788	.9249	220	.05841	3.0521
55	.07712	1.0074	230	.05756	3.1444
60	.07638	1.0885	240	.05674	3.2343
65	.07566	1.1681	250	.05594	3.3216
70	.07494	1.2459	260	.05517	3.4069

WIND PRESSURE.

Velocity.		Pressure per Square Foot, Pounds.	Character of Wind.
Miles per Hour.	Feet per Minute.		
2	176	.030	Perceptible breeze.
3	264	.055	Perceptible breeze.
4	352	.085	Perceptible breeze.
5	440	.133	Perceptible breeze.
7	616	.245	Perceptible breeze.
10	880	.523	Gentle breeze.
15	1,320	1.150	Light wind.
20	1,760	2.000	Light wind.
25	2,200	3.160	Strong wind.
30	2,640	4.500	Strong wind.
35	3,080	6.100	High wind.
40	3,520	7.500	High wind.
45	3,960	10.125	Gale.
50	4,400	12.500	Gale.
60	5,280	18.000	Strong gale.
70	6,160	24.500	Violent gale.
80	7,040	30.200	Violent gale.
90	7,920	41.000	Hurricane.
100	8,800	50.000	Tornado.

STORAGE OF FUEL.

Space required per thousand pounds.

Anthracite coal, prepared "stove" size...... 18 cubic feet.
Bituminous coal, prepared "stove" size..... 20 cubic feet.
Coke.................................... 34 cubic feet.
Cord wood .... 38 cubic feet.
Petroleum, in barrels .... 18 cubic feet.

AQUEOUS VAPOR.

Temperature, F°.	Pressure per Sq. In., Pounds.	Weight per Cu. Ft., Pounds.	Temperature, F°.	Pressure per Sq. In., Pounds.	Weight per Cu. Ft., Pounds.
— 30	.0049	.000017	50	.176	.00058
— 25	.0063	.000023	55	.212	.00069
— 20	.0088	.000030	60	.253	.00082
— 15	.0106	.000039	65	.302	.00097
— 10	.0135	.000050	70	.358	.00115
— 5	.0171	.000063	75	.425	.00135
0	.0216	.000079	80	.502	.00158
5	.0272	.000098	85	.589	.00183
10	.0340	.000121	90	.692	.00213
15	.0423	.000149	95	.809	.00247
20	.0525	.000181	100	.943	.00286
25	.0651	.000222	105	1.094	.00330
30	.0806	.000270	110	1.265	.00380
35	.0998	.000325	115	1.462	.00433
40	.1225	.000400	120	1.682	.00496
45	.1470	.000480	130	2.213	.00640

COMBUSTION.

Rate of Combustion per Sq. Ft. of Grate; Lb. of Coal per Hour.	Air Required per Lb. of Coal.	
	Weight, Pounds.	Volume at 62°, Cu. Ft.
4	23.2	304.85
8	20.2	265.45
12	17.5	230.00
16	15.1	198.43
20	13.0	170.83

SIZE OF CHIMNEYS.

Height of Chimney, Ft.	Rate of Combustion. Coal per Sq. Ft. Grate, per Hour, Lb.	Area of Chimney per Lb. of Coal Burned per Hour, Sq. Ft.
40	11.6	.0108
50	13.1	.0095
60	14.4	.0087
70	15.7	.0080
80	16.8	.0074
90	17.9	.0070
100	19.0	.0067
110	19.9	.0064
120	20.8	.0061
130	21.7	.0059
140	22.5	.0057
150	23.4	.0055

RELATIVE EMISSIVE POWER OF VARIOUS SURFACES.

Cast iron, new	100
Cast iron, rusty	102
Wrought iron, ordinary or "black"	93
Wrought iron, bright, but not polished	72
Surface covered with lampblack, dull	106
Surface covered with white lead powder, dull	106
Two coats of asphaltum paint	106
Two coats of white lead paint, dull	109
Rough bronzing	106
One coat of glossy, white paint	90

NON-CONDUCTING COVERINGS.

Kind of Covering.	B. T. U. Transmitted per Hour per Sq. Ft. Surface, per Degree Difference of Temperature.	Loss Per Cent.
"Manville" sectional and hair felt	0.2169	8.00
Rock wool	0.2556	9.50
Mineral wool	0.2846	10.50
"Champion" mineral wool	0.3166	11.72
"Manville" wool cement	0.3448	12.77
"Manville" sectional	0.3496	12.94
Magnesia	0.3838	14.20
Hair felt	0.4220	15.62
Fire felt	0.5023	18.60
Fossil meal	0.8787	32.54
"Riley" cement	0.9531	35.30
Bare pipe	2.7059	100.00

FLUE RADIATORS—NATURAL DRAFT.

Surfaces.		Heat Emitted per Sq. Ft. per Hour, per Degree Difference.		Total Heat Emitted per Hour, per Degree Difference.	
Extended, Sq. Ft.	Plain, Sq. Ft.	Extended, B. T. U.	Plain, B. T. U.	Extended, B. T. U.	Plain, B. T. U.
A	B	C	D	E	F
57.80	40.40	1.65	1.97	95.37	79.58
6.40	4.24	2.05	2.39	13.12	10.13
63.10	41.20	1.39	1.85	87.81	76.22
7.18	4.50	1.90	2.24	13.64	10.08

RADIATORS—VERTICAL TUBE, PRIME SURFACE.

Total emission of heat per hour, from direct radiators, in still air, per square foot of external surface, per degree difference of temperature.

Difference in Temperature, F°.	Vertical Tubes, Massed.		Vertical Tubes, Single Row.	
	40 Inches High, B. T. U.	24 Inches High, B. T. U.	40 Inches High. B. T. U.	12 Inches High, B. T. U.
50	1.29	1.54	1.46	2.01
60	1.33	1.58	1.50	2.06
70	1.36	1.62	1.54	2.12
80	1.39	1.66	1.58	2.17
90	1.41	1.70	1.62	2.22
100	1.46	1.74	1.65	2.27
110	1.49	1.78	1.69	2.32
120	1.52	1.82	1.73	2.38
130	1.56	1.86	1.77	2.43
140	1.59	1.90	1.81	2.48
150	1.63	1.94	1.85	2.53
160	1.66	1.98	1.88	2.59
170	1.69	2.02	1.92	2.64
180	1.73	2.06	1.96	2.70
190	1.76	2.10	2.00	2.75
200	1.80	2.14	2.03	2.80
210	1.83	2.18	2.07	2.85
220	1.86	2.22	2.11	2.90
230	1.90	2.27	2.15	2.96
240	1.93	2.31	2.19	3.01
250	1.97	2.35	2.23	3.06

INDIRECT RADIATORS—NATURAL DRAFT, EXTENDED SURFACES.

Total emission of heat per sq. ft. of actual surface, per hour, per degree difference in temperature.

Height of Flue, Feet.	Velocity of Air in Feet per Second.	Emission of Heat per Sq. Ft. per Hour, per Degree Difference, B. T. U.
5	2.90	1.70
10	4.10	2.00
15	5.00	2.22
20	5.70	2.38
25	6.30	2.52
30	6.70	2.60
35	7.14	2.67
40	7.50	2.72
45	7.90	2.76
50	8.20	2.80

INDIRECT RADIATORS—FORCED DRAFT, PLAIN SURFACES.

Total emission of heat per sq. ft. of surface, per hour, per degree difference in temperature.

Velocity of Air, Feet per Second.	Heat Emitted, B. T. U.	Velocity of Air, Feet per Second.	Heat Emitted, B. T. U.
3	3.42	12	6.93
4	4.00	14	7.50
5	4.50	16	8.06
6	4.94	18	8.50
7	5.33	20	9.00
8	5.71	22	9.42
10	6.33	24	9.79

LOSS OF HEAT

Through windows and walls, in heat units per hour, for one degree difference in temperature, per square foot of surface.

Character of Surface.	B. T. U. per Hour.
Window, single glass	0.776
Window, double glass	0.518
Skylight, single glass	1.118
Skylight, double glass	0.621
Brick wall, 4 inches	0.680
Brick wall, 8 inches	0.460
Brick wall, 12 inches	0.320
Brick wall, 16 inches	0.260
Brick wall, 20 inches	0.230
Outer doors	0.420
Floors, wooden beams, planked	0.083
Floors, fireproof, floored with wood	0.124
Ceilings, wooden beams, planked	0.104
Ceilings, fireproof construction	0.145
Ordinary wooden walls, lathed and plastered, sheathing 1 inch thick on studding, covered with building paper, weatherboarded	about 0.1

HEATING SURFACE REQUIRED PER HORSE-POWER.

Type of Boiler.	Square Feet.
Cylinder	6 to 10
Return tubular	14 to 18
Vertical tubular	15 to 20
Water-tube	10 to 12
Locomotive	12 to 16
Cast-iron sectional	10 to 14

GRATE SURFACE REQUIRED PER HORSE-POWER.

Type of Boiler.	Square Feet.
Cylinder boiler	.60
Flue	.45
Return tubular	.50
Water-tube	.30
Vertical	.65
Locomotive (stationary)	.40

These amounts are suitable for a rate of combustion of about twelve pounds of coal per square foot, per hour, and should be modified for other rates.

With this rate of combustion, the ratio of heating surface to grate surface, in a return tubular boiler, should be about 45 to 1 with bituminous coal, and 36 to 1 with anthracite.

FLOW OF AIR IN FLUES

By natural draft in cubic feet per minute. Area of flue 1 sq. ft.

Difference in Temperature F°.	Height of Flue in Feet.								
	10	15	20	30	40	50	60	80	100
10	108	133	153	188	217	242	264	306	342
15	133	162	188	230	265	297	325	375	420
20	153	188	217	265	306	342	373	435	485
25	171	210	242	297	342	383	420	485	530
30	188	230	265	325	375	419	461	530	594
40	216	265	305	374	431	482	529	608	680
50	242	297	342	419	484	541	594	680	768
60	266	327	376	460	532	595	650	747	842
70	288	354	407	498	576	644	703	809	910
80	308	379	435	533	616	688	751	866	972
90	326	401	460	565	652	728	795	918	1,029
100	342	419	484	593	684	765	835	965	1,080
125	384	470	541	664	766	857	939	1,085	1,216
150	419	514	593	726	838	937	1,028	1,185	1,325

AREA OF REGISTERS.

RECTANGULAR.

Size of Opening.	Net Area.	Size of Opening.	Net Area.
Inches.	Square Inches.	Inches.	Square Inches.
6 × 10	40	14 × 22	205
8 × 10	53	15 × 25	250
8 × 12	64	16 × 24	256
8 × 15	80	20 × 20	267
9 × 12	72	20 × 24	320
9 × 14	84	20 × 26	347
10 × 12	80	21 × 29	400
10 × 14	93	27 × 27	486
10 × 16	107	27 × 38	684
12 × 15	120	30 × 30	600
12 × 19	152		

ROUND.

Diameter of Opening.	Net Area.	Diameter of Opening.	Net Area.
Inches.	Square Inches.	Inches.	Square Inches.
7	26	18	169
8	33	20	209
9	42	24	301
10	52	30	471
12	75	36	679
14	103	48	1,000
16	134		

PROPERTIES OF LOW-PRESSURE STEAM.

	Pressure per Cubic Foot.	Pressure per Cubic Foot.	Difference.
	Wet.	Dry.	
Steam pressure, absolute.	10.00	74.00	64.00
B. T. U. per pound	1,172.89	1,207.43	34.54
B. T. U. per cubic foot...	31.00	209.30	178.30
Temperature............	193.28°	306.52°	113.24°
Volume per pound.......	37.83	5.767	32.063

BRANCHES TO RADIATORS

(For steam pressures of less than 5 pounds).

ONE-PIPE SYSTEM.

Heating Surface of Radiators.	Diameter of Pipe.
24 square feet or less........................	1 inch.
Above 24, not exceeding 60 square feet.......	1¼ inches.
Above 60, not exceeding 100 square feet......	1½ inches.
Above 100 square feet.......................	2 inches.

TWO-PIPE SYSTEM.

Direct Radiators.

Heating Surface of Radiators.	Steam.	Return.
48 square feet, or less....................	1 in.	¾ in.
Above 48, not exceeding 96 square feet....	1¼ in.	1 in.
Above 96 square feet	1½ in.	1¼ in.

Indirect Radiators.

Heating Surface of Radiators.	Steam.	Return.
30 square feet or less.....................	1 in.	¾ in.
From 30 to 50 square feet..............	1¼ in.	1 in.
From 50 tc 100 square feet..............	1½ in.	1¼ in.
From 100 to 160 square feet..............	2 in.	1½ in.

VELOCITY OF HOT-WATER CURRENTS IN FEET PER SECOND.

Height of Circuit in Feet.	Difference in Temperature.				
	10°	15°	20°	30°	40°
5	.75	.92	1.09	1.33	1.51
10	1.06	1.32	1.55	1.88	2.14
15	1.32	1.63	1.91	2.33	2.60
20	1.50	1.85	2.19	2.66	3.01
25	1.67	2.06	2.46	2.98	3.37
30	1.83	2.26	2.68	3.26	3.71
40	2.12	2.61	3.08	3.76	4.26
50	2.37	2.93	3.47	4.22	4.77
60	2.60	3.20	3.79	4.62	5.22
80	3.00	3.71	4.37	5.32	6.03
100	3.35	4.13	4.89	5.93	6.72

PROPORTION OF GLASS TO HEATING SURFACE.

	Steam.	Hot Water.
For 45° inside temperature, divide glass surface by	8	5
For 50° inside temperature, divide glass surface by	7	4.5
For 55° inside temperature, divide glass surface by	6.5	4
For 60° inside temperature, divide glass surface by	6	3.5
For 65° inside temperature, divide glass surface by	5	3.25
For 70° inside temperature, divide glass surface by	4.5	3

With steam at 5 pounds pressure, and temperature of 227°, the pipes, which are usually 1¼-inch bore, will emit 320 to 360 heat units per hour per square foot of surface; consequently, the ratio of heating surface to glass surface may be about as 1 to 6.

DIAMETER OF HOT-WATER MAINS.

Diameter of mains required to properly supply a given area of direct heating surface. Fall of temperature, 20°. Height of circuit, between 10 and 15 feet.

Diameter of Mains.	Total Estimated Length of Circuit in Feet.									
	100	200	300	400	500	600	700	800	900	1,000
1	20									
1¼	35	20								
1½	56	40	25							
2	116	85	70	50						
2½	220	150	120	100	90					
3	345	240	200	170	150	140	125	110	100	90
3½	500	340	280	245	225	205	190	175	162	150
4	700	485	390	340	310	280	260	240	230	220
4½	925	640	535	460	410	375	345	325	300	295
5	1,200	830	700	600	540	490	450	420	400	380
6	1,900	1,325	1,100	950	850	775	700	650	620	600
7		2,000	1,600	1,400	1,250	1,140	1,050	975	925	875
8				1,970	1,720	1,550	1,440	1,350	1,300	1,250
9							1,900	1,800	1,700	1,620

DIAMETER OF RADIATOR CONNECTIONS.

Fall of temperature, 20°.

Size of Pipe in Inches.	¾	1	1¼	1½	2	2½
Area of direct heating surface in square feet..	16	24	40	60	120	240

DIAMETER OF HOT-WATER RISERS.

Diameter of risers required to properly supply a given area of direct heating surface. Fall of temperature, 20°.

Diameter of Riser.	Story Where Heater is Located.					
	1	2	3	4	5	6
Inches.						
3/4	12	17	21	24		
1	22	32	40	48		
1 1/4	38	56	70	80	88	
1 1/2	66	92	112	132	145	
2	140	196	238	280	310	
2 1/2	240	328	400	470	515	
3	350	490	595	700	770	850
3 1/2	510	705	860	1,010	1,110	1,215
4	700	980	1,190	1,280	1,540	1,660

There is a practical limit to the vertical length of risers that can be used to advantage, especially in the smaller sizes of pipe. If a small riser is extended to a great height, the friction of flow becomes excessive, and the quantity of water delivered will be much smaller than it would be with less height. The limits for the various diameters are about as follows:

Diameter in inches....	3/4	1	1 1/4	1 1/2	2
Height in feet	29	30	45	60	80

SIZE OF HOT-AIR PIPES AND REGISTERS.

First-Floor Rooms.				Second-Floor Rooms.			
Size of Register in Inches.	Diam. of Pipe in In.	Size of Rooms in Feet.	Height of Ceiling in Feet.	Size of Register in Inches.	Diam. of Pipe in In.	Size of Rooms in Feet.	Height of Ceiling in Feet.
12×15	12	16×16 to 18×20	11	10×14	10	16×16 to 18×20	10
10×12 or 10×14	10	14×14 to 15×15	10	9×12	9	14×14 to 16×16	9
9×12	9	12×12 to 14×15	9	8×12	8	10×10 to 13×14	8
8×12	8	8×12 to 13×13	9	8×10	7	7×12 to 12×12	8

EFFECT OF MOISTURE UPON AIR.

Temperature in Degrees Fahrenheit.	Weight of One Cubic Foot of Dry Air, in Pounds.	Weight of Air Displaced by Vapor, in Pounds.	Difference in Weight of One Cubic Foot of Dry and of Saturated Air, in Pounds.
10	.08451	.0002	.00007
20	08275	.0003	.00010
30	.08105	.0005	.00017
40	.07944	.0007	.00026
50	.07788	.0010	.00037
60	.07638	.0014	.00052
70	.07494	.0019	.00078
80	07355	.0027	.00103
90	.07222	.0036	.00128
100	.07093	.0048	.00180
110	.06968	.0063	.00235
120	.06848	.0083	.00315

BREATHING SPACE.

Minimum cubic space required for each person when occupying the following buildings:

Lodging or tenement house......	300 cubic feet.
Schoolroom......................	250 cubic feet.
Barracks........................	600 cubic feet.
Ordinary hospital ward..........	1,000 cubic feet.
Fever or surgical ward..........	1,400 cubic feet.
Stables, each horse.............	1,600 cubic feet.
Stables, each cow...............	1,200 cubic feet.

FLOOR SPACE.

Schoolroom.... 25 square feet for each pupil.
Hospitals.....100 square feet for each bed.
Stables.......100 square feet for each horse or cow.

DISCHARGE OF STEAM THROUGH SMALL ORIFICES.

Pressure of steam not less than 20 pounds per square inch, absolute

Diameter of Aperture.	Weight of Steam Discharged Into the Atmosphere for Each Pound of Absolute Pressure.
$\frac{1}{32}$ inch	.03944 pound
$\frac{1}{16}$ inch	.15770 pound

FORMULAS.

FORMULAS USED IN MENSURATION.

THE PARALLELOGRAM.

h = altitude of parallelogram, expressed in any unit;
b = base of parallelogram, expressed in same unit;
A = area of parallelogram.

$$A = hb. \qquad \text{Art. } \mathbf{375.}$$

$$\left.\begin{array}{l} h = \dfrac{A}{b}. \\ b = \dfrac{A}{h}. \end{array}\right\} \qquad \text{Art. } \mathbf{377.}$$

THE TRAPEZOID.

h = altitude of a trapezoid;
l = length of one of its parallel sides;
l_1 = length of the other parallel side;
A = area of trapezoid.

$$A = h\left(\frac{l + l_1}{2}\right). \qquad \text{Art. } \mathbf{376.}$$

THE TRIANGLE.

A, B, C = the number of degrees in the three angles, respectively.

$$\left.\begin{array}{l} A = 180^\circ - B - C. \\ B = 180^\circ - A - C. \\ C = 180^\circ - B - C. \end{array}\right\} \qquad \text{Art. } \mathbf{382.}$$

A_1 and B_1 = the number of degrees in the two acute angles, respectively, of any right-angled triangle.

$$\left.\begin{array}{l} A_1 = 90^\circ - B_1. \\ B_1 = 90^\circ - A_1. \end{array}\right\} \qquad \text{Art. } \mathbf{383.}$$

a and b = the lengths, respectively, of the two short sides of a right-angled triangle;

c = length of third side, or hypotenuse.

$$c = \sqrt{a^2 + b^2}. \qquad \text{Art. } \mathbf{385.}$$

$$\left.\begin{array}{l} a = \sqrt{c^2 - b^2}. \\ b = \sqrt{c^2 - a^2}. \end{array}\right\} \qquad \text{Art. } \mathbf{385.}$$

h = altitude of given triangle;
b = base of triangle;
A = area of triangle.

$$A = \frac{b\,h}{2} \qquad \text{Art. } \mathbf{386.}$$

$$\left.\begin{array}{l} h = \dfrac{2A}{b}. \\ b = \dfrac{2A}{h}. \end{array}\right\} \qquad \text{Art. } \mathbf{386.}$$

THE POLYGON.

N = number of sides in any regular polygon
D = number of degrees in each interior angle.

$$D = \frac{180\,(N-2)}{N}. \qquad \text{Art. } \mathbf{389.}$$

l = length of side of any regular polygon;
d = perpendicular distance from center of polygon (**i.e.**, center of circumscribing circle) to any side;
N = number of sides;
A = area of polygon.

$$A = \frac{d\,l\,N}{2}. \qquad \text{Art. } \mathbf{390.}$$

THE CIRCLE.

d = diameter of circle;
c = circumference;
A = area;
l = length of arc;
n = number of degrees in arc;

a = area of sector;
a_1 = area of segment;
n_1 = number of degrees in sector;
π = 3.1416

$$c = \pi d. \qquad \text{Art. } \mathbf{402.}$$

$$d = \frac{c}{\pi}. \qquad \text{Art. } \mathbf{403.}$$

$$l = \frac{cn}{360}. \qquad \text{Art. } \mathbf{404.}$$

$$A = \frac{\pi d^2}{4} = .7854 d^2. \qquad \text{Art. } \mathbf{405.}$$

$$d = \sqrt{\frac{A}{.7854}}. \qquad \text{Art. } \mathbf{406.}$$

$$a = \frac{n_1 A}{360}. \qquad \text{Art. } \mathbf{407.}$$

$$a_1 = \frac{4h^2}{3}\sqrt{\frac{d}{h} - .608}. \qquad \text{Art. } \mathbf{408.}$$

THE PRISM, CYLINDER, CONE, AND PYRAMID.

p = perimeter of the base of the prism, cylinder, cone, or pyramid;
h = altitude;
h_1 = slant height of cone;
A = area of convex surface;
a = area of base;
A_1 = total area of outside surface;
V = volume.

$$\text{Prism and cylinder} \left\{ \begin{array}{l} \left. \begin{array}{l} A = ph. \\ A_1 = A + 2a. \end{array} \right\} \qquad \text{Art. } \mathbf{416.} \\ V = Ah. \qquad\qquad\qquad \text{Art. } \mathbf{417.} \end{array} \right.$$

$$\text{Pyramid and cone} \left\{ \begin{array}{l} \left. \begin{array}{l} A = \frac{ph_1}{2}. \\ A_1 = A + a. \end{array} \right\} \qquad \text{Art. } \mathbf{422.} \\ V = \frac{ah}{3}. \qquad\qquad\qquad \text{Art. } \mathbf{423.} \end{array} \right.$$

FRUSTUM OF CONE OR PYRAMID

p = perimeter of upper base of frustum;
p_1 = perimeter of lower base of frustum;
h = altitude of frustum;
h_1 = slant height;
a = area of upper base;
a_1 = area of lower base;
A = convex surface;
A_1 = total surface;
V = volume.

$$\left.\begin{array}{l} A = \left(\frac{p + p_1}{2}\right)h_1. \\ A_1 = A + a + a_1. \end{array}\right\} \qquad \text{Art. } \mathbf{426.}$$

$$V = (a + a_1 + \sqrt{a a_1})\frac{h}{3}. \qquad \text{Art. } \mathbf{427.}$$

THE SPHERE.

a = diameter of sphere;
A = area of surface;
V = volume;
π = 3.1416.

$$A = \pi d^2. \qquad \text{Art. } \mathbf{429.}$$

$$V = \tfrac{1}{6}\pi d^3 = .5236\, d^3. \qquad \text{Art. } \mathbf{430.}$$

THE CYLINDRICAL RING.

a = area of cross-section of ring;
c = circumference of cross-section;
D = mean circumference of ring;
A = convex area of ring;
V = volume of ring.

$$A = Dc. \qquad \text{Art. } \mathbf{431.}$$

$$V = Da. \qquad \text{Art. } \mathbf{432.}$$

FORMULAS USED IN MECHANICS.

MOTION AND VELOCITY.

s = distance traveled by moving body;
v = uniform velocity of body;
t = the time.

$$v = \frac{s}{t}. \qquad \text{Art. } \mathbf{465.}$$

$$s = vt. \qquad \text{Art. } \mathbf{467.}$$

$$t = \frac{s}{v}. \qquad \text{Art. } \mathbf{468.}$$

CENTER OF GRAVITY.

w = weight of smaller body;
W = weight of larger body;
l = distance between centers of gravity of the two bodies;
l_1 = distance from the center of gravity of the two to center of gravity of larger body.

$$l_1 = \frac{wl}{W+w}. \qquad \text{Art. } \mathbf{478.}$$

THE LEVER.

P = the power;
W = the weight;
a = perpendicular distance of power from fulcrum = power arm;
b = perpendicular distance of weight from fulcrum = weight arm;

$a_1, a_2, a_3, \ldots\ldots$ = power arms of compound lever;
$b_1, b_2, b_3, \ldots\ldots$ = weight arms of compound lever.

$$Pa = Wb. \qquad \text{Art. } \mathbf{486.}$$

$$P \times a_1 \times a_2 \times a_3 \times \ldots = W \times b_1 \times b_2 \times b_3 \times \ldots \qquad \text{Art. } \mathbf{490.}$$

WHEEL WORK.

$D_1, D_2, D_3, \ldots\ldots$ = diameters of driving pulley and wheels;
$d_1, d_2, d_3, \ldots\ldots$ = diameters of drum and pinions;
P = power exerted;
W = weight lifted.

$$\left.\begin{aligned} P &= \frac{W \times d_1 \times d_2 \times d_3 \times \ldots\ldots}{D_1 \times D_2 \times D_3 \times \ldots\ldots}. \\ W &= \frac{P \times D_1 \times D_2 \times D_3 \times \ldots\ldots}{d_1 \times d_2 \times d_3 \times \ldots\ldots}. \end{aligned}\right\} \qquad \text{Art. } \mathbf{493.}$$

PULLEYS.

n = number of parts of rope supporting load; one continuous rope being used, and free end not counted;
P = power;
W = weight lifted.

$$\left.\begin{aligned} W &= Pn. \\ P &= \frac{W}{n}. \end{aligned}\right\} \qquad \text{Art. } \mathbf{499.}$$

THE INCLINED PLANE.

l = length of inclined plane;
b = base of plane;
h = height of plane;
P = power;
W = weight.

When the power acts parallel to the plane:

$$P = \frac{w\,h}{l}; \quad W = \frac{P\,l}{h}. \qquad \text{Art. } \mathbf{501.}$$

When the power acts parallel to the base:

$$P = \frac{w\,h}{b}; \quad W = \frac{Pb}{h}. \qquad \text{Art. } \mathbf{501.}$$

THE SCREW.

p = pitch of screw;
r = perpendicular distance from center of screw to line of direction of power;
P = power;
W = weight.

$$\left.\begin{aligned} P &= \frac{Wp}{6.2832\,r} = \frac{Wp}{2\pi r}. \\ W &= \frac{6.2832\,Pr}{p} = \frac{2\pi r P}{p}. \end{aligned}\right\} \qquad \text{Art. } \mathbf{504.}$$

FRICTION ON GUIDES.

P = total pressure on piston;
l = length of main rod;
r = length of crank;
c = coefficient of friction between cross-head and guides;
F = effort required to overcome friction.

$$F = \frac{Prc}{l}. \qquad \text{Art. } \mathbf{515.}$$

CENTRIFUGAL FORCE.

F = centrifugal force in pounds;
W = weight of revolving body in pounds;
R = radius of circle described by body in feet;
N = revolutions per minute.

$$F = .00034\,WRN^2. \qquad \text{Art. } \mathbf{518.}$$

WORK AND ENERGY.

F = force required to overcome the resistance:
S = space through which the resistance acts:
U = work done in foot-pounds;
T = time occupied in minutes;
H = horsepower;
W = weight of a body;
h = vertical distance the body is raised.

$$U = FS = Wh. \qquad \text{Art. } \mathbf{525.}$$

$$H = \frac{FS}{33{,}000\,T} = \frac{Wh}{33{,}000\,T}. \qquad \text{Art. } \mathbf{527.}$$

W = weight of moving body in pounds;
v = velocity of body in feet per second;
E_k = kinetic energy of body in foot-pounds.

$$E_k = \frac{Wv^2}{64.32}. \qquad \text{Art. } \mathbf{529.}$$

LIQUID PRESSURE.

a = area of a submerged surface in square inches;
d = distance in inches of center of gravity of surface from surface of liquid;
w = weight of a cubic inch of the fluid in pounds;
p = pressure on surface of liquid, pounds per sq. in.;
P = total pressure on submerged surface in pounds.

$P = a(dw + p)$. Arts. **539** to **546.**

THE HYDRAULIC PRESS.

a = area of pump plunger;
A = area of main ram or plunger;
p = force exerted on pump plunger;
W = weight lifted or force exerted by main ram.

$$\left.\begin{aligned} W &= \frac{Ap}{a}. \\ p &= \frac{Wa}{A}. \end{aligned}\right\} \quad \text{Art. } \mathbf{550.}$$

From 5% to 15% of the force exerted is absorbed through friction of the cup leathers, the actual amount depending on their age and condition.

PRESSURE ON OBLIQUE SURFACES.

To find the pressure exerted by a fluid in any direction upon a surface:

Rule.—*The pressure exerted by a fluid in any direction upon* **any** *surface is equal to the weight of a prism of the fluid whose base is the projection of the surface at right angles to the direction considered, and whose height is the depth of the center of gravity of the surface below the level of the liquid.* Art. **558.**

FLOW OF WATER IN PIPES.

Discharge from any Orifice.—To find the mean velocity, in feet per second, of any issuing stream:

Let v_m = the mean velocity of discharge in feet per second;

Q = number of cubic feet discharged in one second;

A = area of cross-section of pipe in square feet.

Then, $$v_m = \frac{Q}{A}.$$ Art. **569.**

Mean Velocity of Discharge.

Let v_m = mean velocity of discharge in feet per second;

h = total head in feet = the vertical distance between the level of the water in the reservoir and the point of discharge;

l = length of pipe in feet;

d = diameter of pipe in inches;

f = coefficient of friction.

Then, for straight cylindrical pipes of uniform diameter, the mean velocity of discharge may be calculated by the following formula:

$$v_m = 2.315\sqrt{\frac{h\,d}{f\,l + .125\,d}}.$$ Art. **570.**

NOTE.—The head is always taken as the vertical distance between an imaginary line through the point of discharge and the level of the water at the source, or point from which the water is taken, and is always measured in feet. It matters not how long the pipe is, whether vertical or inclined, whether straight or curved, or whether any part of the pipe goes below the level of the point of discharge or not, the head is always measured as stated above.

When the pipe is very long, compared with the diameter, the following formula may be used:

$$v_m = 2.315\sqrt{\frac{h\,d}{f\,l}}.$$ Art. **571.**

This formula may be used when the length of the pipe exceeds 10,000 times its diameter.

The Actual Head.

The actual head necessary to produce a certain velocity v_m may be calculated by the following formula:

$$h = \frac{f\,l\,v_m^2}{5.36\,d} + .0233\,v_m^2.$$ Art. **572.**

Quantity Discharged from Pipes.

Let d = diameter of pipe in inches;

Q = gallons discharged per second;

v_m = mean velocity of discharge in feet per second.

Then, $Q = .0408\, d^2 v_m$. Art. **573.**

If the diameter of the pipe and the discharge are known, the mean velocity can be found from the following formula:

$$v_m = \frac{24.51\, Q}{d^2}. \qquad \text{Art. } \mathbf{574.}$$

If the head, the length of the pipe, and the diameter of the pipe are given, to find the discharge use the following formula:

$$Q = .09445\, d^2 \sqrt{\frac{h\, d}{f\, l + .125\, d}}. \qquad \text{Art. } \mathbf{575.}$$

To find the value of f, calculate v_m by formula, Art. **571**, assuming that $f = .025$, and get the final value of f from the following table.

$v_m =$	0.1	0.2	0.3	0.4	0.5	0.6
$f =$	.0686	.0527	.0457	.0415	.0387	.0365
$v_m =$	0.7	0.8	0.9	1	1¼	1½
$f =$	.0349	.0336	.0325	.0315	.0297	.0284
$v_m =$	2	3	4	6	8	12
$f =$	.0265	.0243	.023	.0214	.0205	.0193

Necessary Head for Given Discharge.

If it is desired to find the head necessary to give a discharge of a certain number of gallons per second through a pipe whose length and diameter are known, calculate the

mean velocity of efflux by using formula, Art. **574.** Find the value of f (from the table) corresponding to this value of v_m; substitute these values of f and v_m in formula, Art. **572,** and calculate the head. Art. **576.**

VOLUME AND PRESSURE OF GASES.

p = original pressure;
v = original volume;
p_1 = final pressure;
v_1 = final volume.

$$p_1 = \frac{p\,v}{v_1}. \qquad \text{Art. } \mathbf{591.}$$

$$v_1 = \frac{p\,v}{p_1}. \qquad \text{Art. } \mathbf{592.}$$

PUMPS.

Size of Cylinder.

Let G = number of gallons discharged per minute;
S = plunger speed in feet per minute;
d = diameter of cylinder in inches.

$$d = 5.535\sqrt{\frac{G}{S}}. \qquad \text{Art. } \mathbf{618.}$$

Approximate Discharge.

$$G = .03264\,d^2 S. \qquad \text{Art. } \mathbf{619.}$$

Theoretical Discharge.

$$G = .0408\,d^2 S. \qquad \text{Art. } \mathbf{619.}$$

Horsepower of Pump.

G = number of gallons discharged per minute;
h = vertical height of lift in feet;
H = horsepower required.

Then, $H = .00038\,G\,h.$ Art. **620.**

The theoretical horsepower will be two-thirds of the above result.

$$h = \frac{H}{.00038\,G}. \qquad \text{Art. } \mathbf{621.}$$

Size of Pump.

Let S = piston speed per minute;
d = diameter of cylinder in inches;
r = ratio between the length of stroke and diameter of cylinder;
l = length of stroke in feet;
n = number of strokes per minute;
H = horsepower;
P = steam or air pressure per sq. in.

$$\left.\begin{aligned} d &= \sqrt[3]{\frac{504,201.6 \times H}{r P n}}. \\ d &= \sqrt{\frac{42,016.8 \times H}{P S}}. \end{aligned}\right\} \quad \text{Art. } \mathbf{622.}$$

Having obtained the diameter by means of either of the above formulas, the stroke can be found by multiplying the diameter by the value of the ratio r. When the second formula is used, the number of strokes can be found by dividing the piston speed by the length of the stroke in feet.

Since it is easier to extract the square root than the cube root, the second formula is to be preferred.

STRENGTH OF BARS IN TENSION.

W = safe load in pounds;
A = area of minimum cross-section in square inches;
S = working stress in pounds per square inch (see table of Tensile Strengths of Materials).

$$\left.\begin{aligned} W &= A\,S. \\ A &= \frac{W}{S}. \\ S &= \frac{W}{A}. \end{aligned}\right\} \quad \text{Art. } \mathbf{628.}$$

STRENGTH OF CHAINS.

W = safe load in pounds for stud-link chains;
W_1 = safe load in pounds for close-link chains;
D = diameter of iron from which link is made, inches.

$$\left.\begin{array}{l} W = 18{,}000\ D^2. \\ W_1 = 12{,}000\ D^2. \end{array}\right\} \quad \text{Art. } \mathbf{629.}$$

STRENGTH OF ROPES.

C = circumference of **hemp** rope in inches;
W = maximum working load in pounds.

$$\left.\begin{array}{l} W = 100\ C^2. \\ C = .1\ \sqrt{W}. \end{array}\right\} \quad \text{Art. } \mathbf{630.}$$

C = circumference of **wire** rope in inches;
W = maximum working load in pounds;
k = constant: 600 for iron; 1,000 for steel;
c = constant: .0408 for iron; .0316 for steel.

$$\left.\begin{array}{l} W = k\ C^2. \\ C = c\ \sqrt{W}. \end{array}\right\} \quad \text{Art. } \mathbf{633.}$$

STRENGTH OF PILLARS.

C = crushing strength in tons per sq. in. (see table of Crushing Strengths of Materials);
S = sectional area in inches;
L = length in inches;
d = least thickness of rectangular pillar, or diameter of round pillar, in inches;
W = breaking load in tons;
a = constant (see table of Constants for Pillars).

$$W = \frac{C\,S}{1 + \frac{L^2}{a\,d^2}}. \quad \text{Art. } \mathbf{638.}$$

STRENGTH OF BEAMS.

d = depth of beam in inches;
w = width of beam in inches;
d_1 = diameter of cylindrical beam in inches;

L = length between supports in feet
= distance between load and fixed end, in the case of cantilevers;
S = safe transverse strength (see table of Constants for Transverse Strength of Beams);
W = safe load in pounds.

Cantilevers. (Load at End.)

$$W = \frac{d^2 w S}{L}. \qquad \text{Art. } \mathbf{642.}$$

$$W = \frac{.6\, d_1^2 S}{L}. \qquad \text{Art. } \mathbf{643.}$$

If the load is distributed uniformly, multiply the results obtained from the above two formulas by 2.

Beams Supported at the Ends.

$$W = \frac{4\, d^2 w S}{L}. \qquad \text{Art. } \mathbf{644.}$$

$$W = \frac{4\, d_1^2 \times .6\, S}{L}. \qquad \text{Art. } \mathbf{645.}$$

If the load is uniformly distributed, multiply the results obtained by 2.

SHEARING STRENGTH OF MATERIALS.

a = area of cross-section in square inches;
S = safe shearing stress (see table of Shearing Strengths of Materials);
W = safe load in pounds.

$$W = aS. \qquad \text{Art. } \mathbf{649.}$$

STRENGTH OF PIPES AND CYLINDERS.

Let D = maximum internal diameter in inches;
t = thickness of the metal in inches;
P = internal pressure in pounds per sq. inch;
S = safe tensile strength of material in pounds per sq. inch.

$$\left.\begin{aligned} P &= \frac{2\,t\,S}{D}. \\ D &= \frac{2\,t\,S}{P}. \\ t &= \frac{D\,P}{2\,S}. \\ S &= \frac{D\,P}{2\,t}. \end{aligned}\right\} \quad \text{Art. } \mathbf{651.}$$

RULES USED IN PLUMBING AND DRAINAGE.

THE VACUUM GAUGE.

To compute the height to which water will rise, the gauge pressure being known:

Rule.—*Divide the gauge pressure by .43404. The quotient will be the height in feet.* Art. **831.**

EXPANSION OF WATER.

To compute the change of volume due to change of temperature:

Rule.—*Divide the product of the original volume and the comparative volume at final temperature by the comparative volume at original temperature.* Art. **846.**

RULES USED IN GAS AND GAS FITTING.

FLOW OF GAS.

If the rate of flow through any certain length of pipe is known, the volume which will be delivered by a longer or shorter pipe of the same diameter, in the same time (the pressure and density of gas remaining the same), may be found by the following rule:

Rule.—*Multiply the volume delivered by the pipe of given length by the square root of that length, and divide the product by the square root of the proposed length. The quotient will be the delivery of the proposed length.* Art. **1065.**

The volume that will be delivered under different pressures may be computed by the following rule:

Rule.—*Multiply the volume delivered at the given pressure by the square root of the proposed pressure, and divide the product by the square root of the given pressure. The quotient will be the delivery at the proposed pressure.* Art. **1066.**

The actual **quantity** of the gas passing through a pipe in a given time is computed by correcting the volume for temperature and pressure, reducing it to a volume at standard temperature of 32° and standard pressure of 1 inch of water. The correction for temperature may be made by use of the following rule:

Rule.—*Multiply the measured volume by the actual temperature plus 460, and divide the product by 492. The quotient will be the volume at 32°.* Art. **1075.**

To make the correction for pressure:

Rule.—*Multiply the volume by the pressure in inches of water plus 407, and divide the product by 408. The quotient will be the volume at 1 inch pressure.* Art. **1075.**

ILLUMINATION.

Amount of Light Required.

To find the number of ordinary 5-foot batswing burners required to properly illuminate a church or other large room:

Rule.—*Divide the area of the floor of the room by 40, the quotient will be the number of bnrners required.* Art. **1206.**

If there are balconies, etc., extra lights must be provided for them by the same rule. The divisor given may be varied from 40 to 80 to suit smaller rooms, such as are found in ordinary dwellings. The reflection from the walls is proportionally greater in small rooms; therefore, a less number of burners is required in proportion to the actual floor space.

One 5-foot burner is assumed to give a light of 16 candle power. The amount of light required is, therefore, 16 candle power to a floor space of 40 square feet in large rooms, to 80 in small ones, or .4 to .2 candle power per square foot of floor space.

FORMULAS USED IN ELECTRIC-LIGHT WIRING AND BELL WORK.

OHM'S LAW.

The strength of an electric current in any circuit is directly proportional to the electromotive force developed in that circuit, and inversely proportional to the resistance of the circuit; i. e., is equal to the quotient arising from dividing that electromotive force by the resistance. Art. **1223.**

Letting E = electromotive force in *volts*;
R = resistance in *ohms*;
C = current in *amperes*,

$$C = \frac{E}{R}. \qquad \text{Art. } \mathbf{1224.}$$

RESISTANCE OF CONDUCTORS.

Let R = the required resistance;
L = length of conductor;
R_1 = resistance per 1,000 ft. of conductor.

$$R = \frac{L R_1}{1{,}000}. \qquad \text{Art. } \mathbf{1227.}$$

WIRING FOR ELECTRIC LIGHT.

110-Volt Two-Wire System.

R_f = resistance per foot of wire;
E = drop in volts;
C = current;
A = area of wire in circular mils;
L = length of wire in feet;
NF = lamp-feet, or number of lamps multiplied by the distance from the source of current to those lamps.

$$\left.\begin{array}{ll} & R_f = \dfrac{E}{C L}. \\ \text{Also,} & R_f = \dfrac{E}{NF}. \end{array}\right\} \qquad \text{Art. } \mathbf{1280.}$$

$E = R_f N F.$ Art. **1286.**

The corresponding wire may be found from the table of Copper Wire Data.

55-Volt Two-Wire System.

$$R_f = \frac{E}{2 N F}.$$ Art. **1284.**

$$E = 2 R_f N F.$$ Art. **1285.**

WIRE FOR LOOP CIRCUIT.

Rule.—*In determining the size of wire for a loop circuit, multiply the number of lamps by one-half the distance, in feet, around the loop. This will give the lamp-feet N F, and is used in the formulas already given.* Art. **1288.**

HEAVY CONDUCTORS.

110-Volt Two-Wire System.

$$A = \frac{10.8 \, N F}{E}.$$ Art. **1289.**

SIZE OF CONDUCTORS FOR THREE-WIRE SYSTEM.

$$R_f = \frac{2 E}{N F},$$ Art. **1292.**

or, for wires of extra large capacity,

$$A = \frac{5.4 \, N F}{E}.$$ Art. **1292.**

LOSS OF POTENTIAL ON LINE.

Let V_1 = initial voltage;
V = voltage at the lamp terminals;
E = drop in volts;
p = percentage of loss.

$$\left.\begin{aligned} V_1 &= \frac{100 \, V}{100 - p}. \\ E &= V_1 - V. \end{aligned}\right\}$$ Art. **1291.**

RULES AND FORMULAS USED IN HEATING AND VENTILATION.

VOLUME OF HEATED WATER.

The increase in volume caused by heating water may be computed by

Rule.—*Multiply the volume at the lower temperature by the difference in the comparative volumes at the original and final temperatures.* Art. **1360.**

EXPANSION OF BARS AND PIPES.

Rule.—*Multiply the length of bar or pipe in feet by the number of degrees of change in temperature. Multiply this product by the coefficient given in the table of Expansion of Materials for the material employed. The result will be the change in length in inches.* Art. **1362.**

HEAT REQUIRED TO RAISE TEMPERATURE OF BODIES.

Rule.—*To find the number of B. T. U. required to raise the temperature of a body a given number of degrees, multiply the specific heat of the body by its weight in pounds and by the number of degrees.*

Or, let U = number of B. T. U. required;
c = specific heat of body;
W = weight of body in pounds;
t = temperature of body before being heated;
t_1 = temperature of body after being heated.

Then, $U = c\,W(t_1 - t)$. Art. **1365.**

TEMPERATURE OF MIXTURES.

Rule.—*To find the temperature of a mixture of several substances, multiply together the weight, specific heat, and temperature of each substance separately and add the products. Next, multiply together the weight and specific heat of each of the substances separately, and add these products.*

Divide the former sum by the latter. The result will be the temperature of the mixture. Art. **1367.**

MEASURING TEMPERATURE OF HOT BODY.

Rule.—(*a*) *Multiply together the weight and specific heat of each substance separately, add the products, and multiply the sum by the temperature of the mixture.* (*b*) *Then, multiply together the weight, specific heat, and temperature of each substance separately, except the one whose temperature is to be found; add the products and subtract the sum from the result obtained in* (*a*). (*c*) *Divide the result obtained in* (*b*) *by the product of the weight and specific heat of the substance whose temperature is to be found, and the result will be the temperature of the body.* Art. **1368.**

MIXTURE OF STEAM AND WATER.

Rule.—*When steam and water are mixed, the steam condenses. To find the final temperature of the mixture, add together the latent heat and the temperature of the steam and multiply the sum by the weight of the steam. To this product add the product of the weight and temperature of the water, and divide the sum so obtained by the sum of the weights of the steam and water. The quotient will be the temperature of the mixture.*

That is, $t = \frac{W(L + t_1) + w\,t_2}{W + w}$. Art. **1372.**

CENTIGRADE AND FAHRENHEIT SCALES.

To change Centigrade temperatures into their corresponding Fahrenheit values:

Rule.—*Multiply the temperature, Centigrade, by $\frac{9}{5}$ and add 32°; the result will be the temperature Fahrenheit.* Art. **1392.**

To change Fahrenheit temperatures into their corresponding Centigrade values:

Rule.—*Subtract 32° from the temperature, Fahrenheit, and multiply by $\frac{5}{9}$, and the result will be the temperature Centigrade.* Art. **1393.**

Expressing these two rules by means of formulas:

Let t_c = temperature Centigrade;

t_f = temperature Fahrenheit.

Then, $$t_f = \frac{9}{5} t_c + 32°,$$

and $$t_c = \frac{5}{9} (t_f - 32°).$$ Art. **1393.**

QUANTITY OF HEAT CONTAINED IN AIR.

Rule.—*Multiply together the given volume of the air, the number of degrees through which it is cooled, and the amount of heat contained in 1 cubic foot of air at the original temperature given, as shown in columns 3 and 6 of the table of Properties of Air. This product should then be divided by the original temperature. The quotient will be the amount of heat given off in heat units.* Art. **1422.**

WEIGHT OF AIR.

The weight of a cubic foot of air at any temperature and pressure may be calculated by

Rule.—*Multiply the pressure in pounds per square inch by 2.702, and divide the product by the absolute temperature.*

Or, let W = weight of 1 cubic foot of air in pounds;

p = pressure in pounds per square inch;

T = absolute temperature.

Then, $$W = \frac{2.702 p}{T}.$$ Art. **1423.**

VOLUME AND WEIGHT OF AIR.

Volume.

Rule.—*Reduce both the original and final temperatures to absolute temperatures. Multiply the original volume by the final absolute temperature and divide by the original absolute temperature. The quotient will be the final volume.*

Or, let V = original volume;

V_1 = final volume;

T = original absolute temperature;

T_1 = final absolute temperature.

Then, $$V_1 = \frac{V T_1}{T}.$$ Art. **1424.**

Weight.

The change in weight of a given volume of air may be computed from the following

Rule.—*Multiply the original weight by the original absolute temperature, and divide the product by the final absolute temperature. The quotient will be the final weight.*

Or, let W = original weight;
W_1 = final weight;
T = original absolute temperature;
T_1 = final absolute temperature.

Then, $W_1 = \frac{W\,T}{T_1}$. Art. **1425.**

VELOCITY OF AIR IN CHIMNEYS AND VENTILATING FLUES.

Rule.—*Multiply the height of the chimney in feet by the difference in temperature of the gases and of the atmosphere in degrees, and divide by the absolute temperature of the atmosphere. Extract the square root of the quotient, and multiply it by 8.02. The result will be the theoretical velocity sought.*

Or, let t = temperature of the atmosphere;
t_1 = temperature of chimney gases;
T = absolute temperature of atmosphere;
H = height of chimney in feet;
v = velocity in feet per second.

Then, $v = 8.02\sqrt{\frac{H(t_1 - t)}{T}}$. Art. **1433.**

MEASUREMENT OF HUMIDITY.

Rule.—*Having found the dew point, ascertain from the table of Aqueous Vapor the weight of a cubic foot of vapor at that temperature; this divided by the weight of a cubic foot of vapor at the temperature of the atmosphere expresses the **relative humidity**.* Art. **1479.**

HUMIDITY AND EVAPORATION.

The amount of water which must be evaporated and added to the air supply to maintain any certain degree of humidity may be found by the following rule:

Rule.—*Ascertain the weight of moisture in the air before it is heated, and compute the weight of moisture required to produce the desired degree of humidity in the same weight of air at the temperature at which it is to be used; the difference between the quantities of moisture thus found will be the amount of moisture to be supplied.* Art. **1481.**

COMBUSTION OF FUEL.

Amount of Air Required.

Rule.—*To find the air required to burn a given fuel: To the carbon contained in the fuel add three times the hydrogen, multiply the sum by 1.52, and the result will be the air required in cu. ft. at a temperature of 62° F.*

Or, let A = the number of cu. ft. of air required for the combustion of a given fuel;
C = the percentage of carbon;
H = the percentage of hydrogen,

C and H being expressed as so many parts in 100.

Then, $$A = 152 \times \frac{C}{100} + 457 \times \frac{H}{100},$$

or $$A = 1.52\,(C + 3\,H), \text{ very nearly.}$$ Art. **1500.**

Heat of Combustion.

Rule.—*To find the heat of combustion of a pound of fuel, multiply the percentage of carbon by 145 and the percentage of hydrogen by 620. Add the products, and the sum will be the required heat of combustion in B. T. U.*

Or, let B = B. T. U. produced by the combustion of a fuel;
C = percentage of carbon;
H = percentage of hydrogen.

Then, $B = 14{,}500 \times \frac{C}{100} + 62{,}000 \times \frac{H}{100}$,

or $B = 145\,C + 620\,H$. Art. **1508.**

Evaporation.

Rule.—*To find the number of pounds of water at 212° evaporated by a pound of fuel, divide the heat of combustion of the fuel by 966.* Art. **1509.**

DRAFT PRESSURE.

The draft pressure which should be produced by a chimney of given height may be found thus:

Rule.—*Ascertain the weight of a column of air one foot square and as high as the chimney, at the atmospheric temperature, and deduct from it the weight of an equal volume of the hot chimney gases, at the average temperature prevailing in the chimney; the difference will be the draft pressure in pounds per square foot of area.*

This may be converted into inches of water by multiplying the pounds per square foot by .193, or dividing by 5.2. Art. **1525.**

SURFACE OF DIRECT RADIATORS.

(Wm. J. Baldwin.)

Rule.—"*Divide the difference between the temperature at which the room is to be kept and that of the coldest outside atmosphere by the difference between the temperature of the steam pipes and that at which you wish to keep the room, and the quotient will be the square feet or fraction thereof of plate or pipe surface to each square foot of glass, or its equivalent in wall surface.*" Art. **1561.**

AMOUNT OF HOT AIR REQUIRED FOR HEATING.

The loss of heat per hour by conduction through windows, walls, etc., being given, and also the *temperature* ot the hot-air supply and the desired temperature of the room, the required volume per hour may be computed as follows:

Rule.—*Multiply the amount of heat lost by conduction per hour, in heat units, by 58, and divide the result by the difference in degrees between the given temperatures of the room and the hot-air current. The quotient will be the required volume of hot air in cubic feet per hour.* Art. **1571.**

TEMPERATURE OF HOT-AIR SUPPLY.

Rule.—*Multiply the amount of heat lost by conduction in heat units per hour by 58, and divide the result by the given volume of the air-current. Add the quotient to the desired temperature of the room; the sum will be the required temperature of the hot-air supply.* Art. **1572.**

RULES IN STEAM HEATING.

SIZE OF STEAM MAINS OR PRINCIPAL RISERS.

Rule.—*Divide the amount of direct heating surface in square feet by 100; divide the quotient by .7854; then extract the square root of the quotient; the result will be the diameter of the pipe in inches.* Art. **1745.**

AMOUNT OF RADIATOR SURFACE.

Rule.—*Multiply the square of the diameter of the pipe in inches by .7854; then multiply the result by 100; the result is the total amount of heating surface, in square feet, which the pipe will supply.* Art. **1746.**

RULES IN HOT-WATER HEATING.

HEIGHT OF CIRCUIT.

Size of Pipes.

The proper size of a pipe having been determined for a given service on the first floor, the diameter for equal service on higher floors—the temperatures remaining the same—may be found by multiplying by the following factors:

	Story 2d	3d	4th	5th
Factors	.87	.80	.76	.73

Art. **1816.**

Heating Surface.

The area of heating surface that may be properly supplied by a pipe of given diameter will increase as the circuit is made higher. If the area which is known to be right for a given size of pipe on the first floor be taken as 1, the areas on the upper floors will increase in the following order:

	Story 2d	3d	4th	5th
Proper area heating surface....	1.40	1.70	1.98	2.20

Art. **1816.**

RULES USED IN FURNACE HEATING.

SIZE OF PIPES.

Dwelling Houses.

The area of the pipe in square inches may be found by the

Rule.—*For rooms on the first floor having only a moderate exposure, divide the volume of the room in cubic feet by 30, or by 25 to 20 for rooms having great exposure.* Art. **1899.**

For second-floor rooms, the divisor may range from 35 to 25, and for third-floor rooms, from 40 to 30.

A more accurate method is to proportion the area of the pipes to the cooling surfaces in the rooms. This may be done by the use of the

Rule.—*For rooms on the first floor, add together the total glass surface and $\frac{1}{4}$ of the area of the exposed walls in square feet, and multiply the total by 1.5; the product is the proper area of the pipe in square inches. For second-story rooms, multiply by 1 to 1.25, according to the exposure; and for the third story, by .75 to 1.* Art. **1900.**

Schools, Halls, Churches, Etc.

Having found the quantity of air required per minute, the size of the pipes may be computed by dividing the required volume by the velocity of the air-current. In all ordinary cases this may be safely assumed at 4 feet *per second* at the first floor, 5 feet at the second floor, and 6 feet per second at the third floor.

Another method, equally good, is to assume that *one square inch of stack, or flue, area will supply 100 cubic feet of air per hour at the first floor, 125 at the second, and 150 at the third floor.*

It is assumed in the foregoing rules that the average temperature of the hot air in the flues is about 120°, and that the air is moved solely by natural draft. Art. **1901.**